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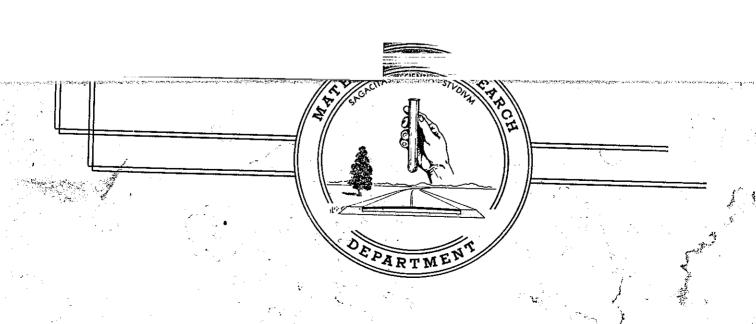
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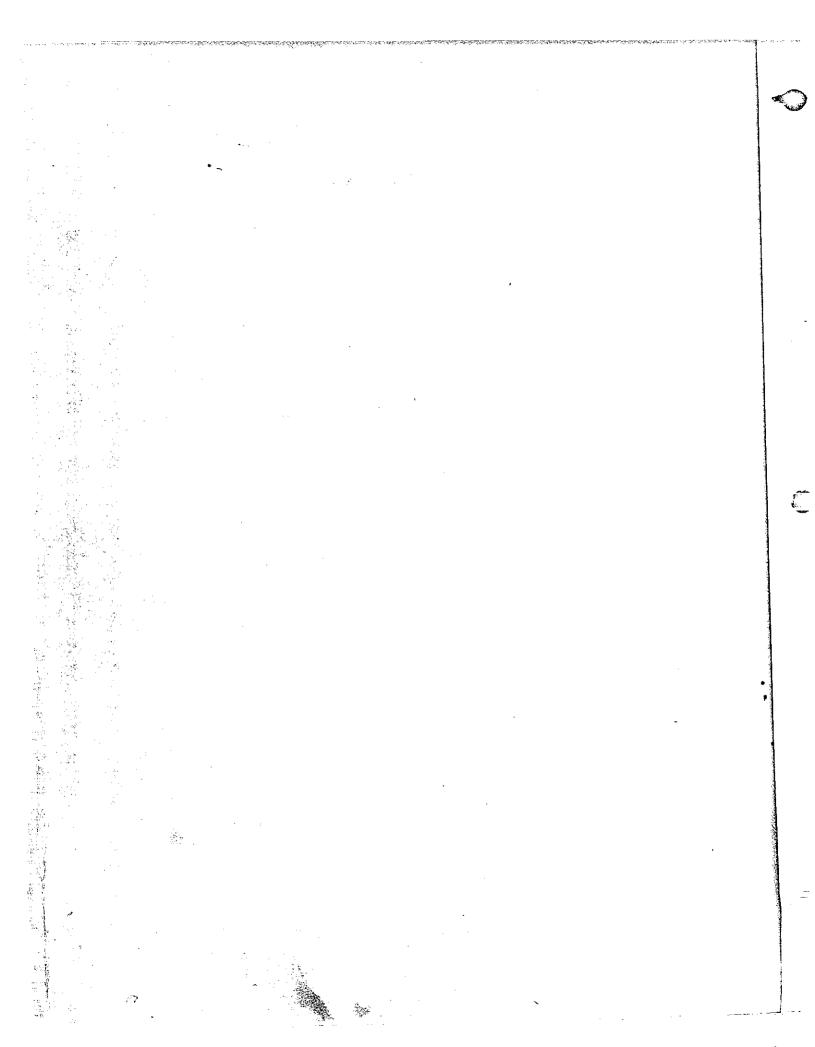


STATE OF CALIFORNIA DEPARTMENT OF PUBLIC WORKS DIVISION OF HIGHWAYS

A REPORT ON THE
PROPERTIES AND WELDING CHARACTERISTICS OF
STRUCTURAL T-1 STEEL

56-13





State of California Department of Public Works Division of Highways Materials and Research Department

April 2, 1956

Laboratory Project Authorization No. 6046

F. W. Panhorst Assistant State Highway Engineer Bridge Department Public Works Building Sacramento, California

Dear Sir:

Submitted for your consideration is:

A REPORT OF

THE PROPERTIES AND WELDING CHARACTERISTICS

OF STRUCTURAL T-1 STEEL

Very truly yours,

F. N. Hveem

Materials and Research Engineer

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Manual Welding Techniques

Exhibit 29.

limits specified by the electrode manufacturers. The manual welding was executed by State certified journeyman welders in the presence and under the direction of a laboratory representative. The plates were welded in a flat position (see Exhibit 29). After each pass slag was cleaned from the welds with a welder's slagging hammer and a wire brush.

The welding was started with the plates at room temperature (without preheat). The time between welding passes was controlled, using both a pyrometer and temperature crayons, such that the temperature of the plate 1 inch from the weld did not exceed 400°F. Each plate was cooled normally (by air convection) to room temperature after the weld was finished.

The power for the manual welding was provided by a General Electric 300 ampere direct current welding machine. The welding amperage settings and polarity recommended by the electrode manufacturer were followed closely. These settings were dependent on the type and size of electrode, the type and size of groove, the fitup, the plate thickness, and the weld pass number.

The welds were radiographically inspected, using gamma ray techniques, for defects equal or exceeding 2% of the plate thickness in dimension. This inspection revealed inclusions in the A. O. Smith weld on the 1" plate, and the Unionmelt weld on the ½" plate. The former was trimmed such that defective portions of the weld were discarded, and the latter was rewelded. Radiographic inspection revealed no further internal defects in all of the welds tested.

The welding of the test plates proceeded smoothly with no spatter, and it was completed without incident. These welds represent the type that may be expected from fabricating shops operating under normal rather than ideal conditions and using the welding processes, procedures, and electrodes listed in this report.

FATIGUE SPECIMEN

The fatigue machine was designed to utilize a specimen (see Exhibits 121 through 124) of relatively large cross-sectional area 3/4" diameter through the maximum stress point, which was located at the base of the fillet. This large cross-section was necessary in order to incorporate as much weld material into the high stress area as could be effected. The specimen as shown was designed with extended non-tapered tail and grip sections in order to lower machining costs and to facilitate easier use in the fatigue machine. The welded fatigue specimens were prepared from the welded plate, keeping the welds at the fillet root as shown in Exhibits 123 and 124. fillet radius was made as large as possible in order to reduce the fillet notch effect. The resulting notch coefficient of 1.05 for this fillet radius was not considered of sufficient magnitude to detract from establishing the nominal stresses on account of an undetermined notch effect introduced by the weld itself. Fatigue tests were not performed on the 2" welded T-1 plate.

FATIGUE MACHINE

A single-end rotating cantilever fatigue machine was used to perform all fatigue testing. This machine (see Exhibits 120 and 122) was driven at 6000 rpm through a Cleveland Variable Speed gearbox by a 12 hp motor. The nominal fiber stresses, which the machine imposed on a specimen at the fillet root, were calibrated statically with a load cell and plotted against the weights and lever arms used (see Exhibit 121). The weight of the specimen and tail collet, and the changes in leverage caused by the deflection of the tail or cantilevered end of the specimen were considered in the load calibration of the machine. Attempts at dynamic calibration using SR4 strain gauges were unsatisfactory and are not tabulated. Cycles (total revolutions) were counted with a Berkeley Electronic Counter and checked against the product of the test period in minutes multiplied by the revolutions per minute.

As reported below, static and dynamic deflections at the cantilevered end of the specimens were measured electronically with a differential transformer. The dynamic temperatures of the critical or maximum stress section were measured with a thermocouple through a slip ring.

A series of fatigue tests were run with ASTM A-7 steel in order to acquire operating experience; to observe the performance of the machine; and, based on these observations, to make any necessary modifications in procedures. The data thus acquired was used as a basis for the qualitative comparison of this machine with other fatigue machines in order to ascertain in a general way its effectiveness as a fatigue testing device. The value of 30,800 psi obtained for the endurance limit of A-7 steel (not using the notch factor of 1.05) compared favorably with the 32,000 psi endurance limit listed for hot rolled 0.20% carbon steel in the ASM Metals Handbook, page 119. Table I.

Eight of the welded and parent metal specimens which were stressed above 50,000 psi and which ran longer than 2 x 10⁶ cycles, failed through the gripped section. This breakage appears to have been aggravated by fretting corrosion plus a possible third harmonic vibration. The computed resonance of the section through the grip was near 2000 cycles per minute, whereas the speed employed was 6000 rpm. However, the data from these specimens was in line with the balance of the specimens and therefore it is considered that the results were not adversely affected.

FATIGUE TEST PROCEDURE

Five fatigue tests were made on each welded plate. A nominal stress of 50% to 60% of the ultimate strength of the weld was applied in the initial test from each plate, and the load was reduced on successive test specimens until the final specimen endured 10% cycles without failure.

These final specimens were retested (Footnote 1) at a higher stress (damage checked) in order to observe how the cyclic stress history of the specimens affected their fatigue strength. This information was used to check the critical points on the S-N curve.

TREATMENT OF FATIGUE DATA

The static and dynamic deflections of the cantilevered end of the specimen were not considered reliable in establishing the stresses in the specimen on account of (1) the undefinable notch effect of the weld and (2) the uncertain interpretation of the dynamic reading. The dynamic temperatures recorded (which were often 70° or more above room temperature) were not sufficiently precise to be informative, as the recording method was not free enough from heat loss and other variables to be effectively analyzed without further test information. Therefore, the deflection and temperature data is not included in this report.

The S-N diagram (stress versus cycles to failure) for the T-1 steel and for each weld tested was plotted on a log-log system of coordinates. (See Appendix Section F). The best line through and the negative probable error for each set of data was calculated from least square formulas and entered on a graph with the appropriate data. Since a large number of the tests could not be made, the data of the weld fatigue tests were not separated according to plate thickness. The scatter was such that it was necessary to combine all the fatigue data from each weld process in order to evaluate this data with logical results.

The ordinates of the horizontal portions of the S-N diagrams corresponding to the endurance limits were estimated from the data by visual inspection. These estimates of the endurance limits are considered as the maximum that can be permitted on the basis of these test results.

OTHER PHYSICAL SPECIMENS

The other physical test specimens, tensiles, bends, impacts, and hardness surveys, were prepared and were examined according to standard ASTM and AWS procedures where such were specified. The yield strengths of the butt weld tensile specimens were determined by the "drop of the beam" or the "halt of the dial" method. The 0.2% offset yield strengths of all the parent metal specimens (except the 2" strap tensile from the $\frac{1}{2}$ " plate and the .505" diameter tensiles) were taken from the corresponding stress-strain curves. The net ultimate and

Footnote 1. When the fatigue strength of a retested specimen exceeds its probable fatigue strength in the virgin state, it is said to have been "coaxed" to a higher fatigue strength. It is possible to raise the endurance limit of a specimen about 25% by subjecting it to a series of 4 x 10° or more stress reversals starting with an applied stress below the virgin endurance limit and increasing the stress slightly with each series of reversals until a new endurance limit is reached. This practice is called "coaxing".

yield strength reported for each thickness of the parent metal was an average taken from all the parent metal tensile specimens for that thickness. This ultimate strength was used in calculating the joint efficiencies of the various welds used on the corresponding plate. The net percent reduction of areas illustrated in Exhibit 8A for the parent metal plate, were based on the 2" and 8" strap tensile specimens, because the cross-section of these tensiles could be compared with that of the butt weld tensile specimens. Similarly, the percent elongation reported for the parent metal was taken from the 2" strap tensiles in order that these figures might be compared with the butt weld tensile specimens.

The tensile strengths listed on the S-N diagrams were taken from standard .505" diameter weld metal plug tensile specimens. These weld metal samples were prepared by fusing electrodes to fill a form about 1" x 1" x 12" in dimension, made from the T-1 plate, and were then machined into a tensile specimen as noted. Tensile testing was performed with a 200,000 lb. capacity Baldwin Universal Testing machine and a 60,000 lb. capacity Riehle machine.

The V notch Charpy impact tests, which were conducted according to ASTM procedures at 0° Fahrenheit, show a wide divergence of the resulting energies absorbed in fracturing the specimens. However, the averages surpass the 23 foot pound minimum requirement for keyhole Charpy impact energy at 0° F. which is listed in Military Specifications #E-18038 (ships). The keyhole Charpy impact test is considered less severe than the V notch test referred to above. This 23 foot pound minimum is an acceptable value for comparative purposes, and it indicates that unfavorable brittleness was not encountered in (1) the parent metal, (2) the heat affected zone, and (3) the weld metal. This applies to all samples taken from $\frac{1}{2}$ ", 1", and $1\frac{1}{2}$ " butt welded joints (see Exhibit 3).

The hardness survey specimens were prepared by slicing a small sample cross-section from the welds at right angles to the axes of the joints. These cross-sections were smoothed on a belt sander and macro-etched to locate the weld and weld affected areas clearly. A 1/8" grid pattern was drawn on the surface of each cross-section. Rockwell scale hardness measurements in each piece were taken from the intersections in the grid. These measurements are plotted on graphs shown in Exhibits 145 through 164 on Appendix Section 6.

A number of parent metal pieces were flame cut and machine cut from the sample T-1 plates. These were subjected to side bending. The untreated samples of flame cut edges failed to pass these bend tests (see Exhibit 14). These failures were attributed to hardened metal, slag, scale, and notches remaining on the edges from the flame cutting and scarfing operations.

V. DISCUSSION

The test results for T-1 steel verify the physical properties specified for that steel by the U. S. Steel Corporation. The yield, ultimate strength, and fatigue properties varied inversely with the thickness of the plate as may be noted from Exhibits 5 through 12, with net yield strengths dropping from 120,100 psi for $\frac{1}{2}$ " thick plate to 93,100 psi for $1\frac{1}{2}$ " thick plate, net ultimate strengths from 130,200 psi to 103,500 psi and rotating bending endurance limits from 58,600 psi to 51,200 psi. Ductility increased with plate thickness and varied inversely with tensile strength, with elongations on the 2" strap tensiles varying from 27.5% to 43.5%. The tensile failures of the parent metal were of the 50% to 100% ductile type of fractures. All the cold bends went 180° without failure.

The parent metal in a preliminary study exhibited a fibrous structure parallel to the rolling direction in failed sections. Microscopic examination revealed some fine porosity parallel to this rolling direction. These facts indicate the possibility of directional properties, although this has not been examined directly. Further metallographic studies are contemplated.

Flame cut edges were so hard that they were difficult to machine. These flame cut sample edges failed in bend tests. Scale and slag remaining from the flame cutting operations are often trapped in subsequent welding. Therefore, prior to welding, a mechanical treatment was necessary in order to remove hardened material, slag, scale, and notches from the flame cut edges. The possibility of developing or modifying a flame cutting procedure to overcome these disadvantages is suggested.

The Aircomatic process using A632 electrode wire with a manual #21 gun and a gas shield of 98% argon and 2% oxygen, produced welds with the most desirable all around physical properties of any tested. These welds showed very little porosity, and they meet the requirements for soundness in the critical or primary welding better than welds produced by the other processes tested.

The A. O. Smith manual low hydrogen process using SW-91 electrodes (Ell016 tentative) produced welds with porosity and visible inclusions apparent in about 10% of the failed cross sections. Even so, the joints welded by this process possessed good tensile and fatigue strength with moderate ductility and notch sensitivity. The Unionmelt submerged arc automatic process using Oxwell 866 electrode wire produced ductile welds of moderate tensile strength and notch sensitivity, with good fatigue strength. Here again the welds contained numerous inclusions with visible porosity in about 10% of the failed sections. The test data for both of these processes indicate that if sound welds are produced by either, they will have excellent physical properties despite the moderate or low average properties recorded in this report which resulted from inclusions in some of the welds tested. However, the apparent difficulty encountered in producing a sound weld consistently by either of these processes limits their desirability in critical welding applications. If these problems can be overcome, the use of a submerged arc process would be satisfactory.

The Airco manual low hydrogen processes using E10016 and E12015 electrodes produced welded joints with moderate to excellent tensile strength and ductility, but with endurance limits barely exceeding that of A-7 structural steel. The results indicate that in structural members not subject to excessive fatigue (i.e., fatigue exceeding the capacities of A-7 steel), the other physical properties of these welds might be employed to advantage. Notice from the test data that butt welded joints made with the E12015 electrodes have no positive strength advantage over those made with E10016 electrodes (see Exhibits 5 through 12). Test results, contrary to usual findings, also indicate that the endurance limits for butt welded joints prepared using the harder E12015 electrodes are not greater than for joints prepared with the softer E10016 and E11016 electrodes. The joints prepared from E10016 electrodes reflect the greater strength of the 1" and ½" plate. This is possibly due to dilution of the weld metal by the plate. The E11016 electrode would appear to be ideal for welding T-1 steel. Therefore, the advantages of ductility realized by using E10016 and E11016 electrodes, more than offset the questionable strength advantage of the harder E12015 electrode.

VI. CONCLUSIONS

- (1) Structural T-1 steel may be satisfactorily welded for structural purposes using both automatic and manual processes providing the welding procedures are carried out properly.
- (2) A joint efficiency of 95% for structural T-1 steel welded joints can be obtained if based on the usually specified mechanical properties of T-1 steel for structural use. These are:

Ultimate Strength Yield Strength Elongation in 2" 105,000 psi 90,000 psi % Minimum for .505 tensile specimens

18% for 1/4" to 2" incl.
17% for 2" to 4" incl.
16% for 4" to 6" incl.

plate thickness plate thickness plate thickness

- (3) Narrow tolerances in operating procedures are necessary for the consistent production of satisfactory welds of T-1 structural steel. This will necessitate rigorous prequalification of all welding operators and procedures and will allow no deviation from established procedure.
- (4) The inspection methods and techniques used to control the welding procedures employed during this test program conformed to Calif. Test Method 601. These should be followed during actual fabrication except that the specified AWS standard guided bend test may be modified by the use of a bending jig that will produce 13% rather than 20% elongation in the extreme fibre of the bend specimen.
- (5) The more ductile E-10016 and E-11016 electrodes produced butt joints with strengths approximately equal to those provided by butt joints welded using the harder E-12015 electrodes. It is considered that the use of E-100 and E-110 series of low hydrogen electrodes will result in an over-all more satisfactory structural weld than can be made by using the E-120 low hydrogen electrodes.
- (6) Wherever possible, automatic flame cutting processes should be used when flame cutting T-1 steel. These operations should be so adjusted and controlled as to provide smooth and even flame cut edges and to minimize the hardening of these edges.
- (7) T-1 steel flame cut edges which are to be welded should be mechanically treated to remove hardened metal, oxides, scale, and surface irregularities in order to prevent oxidized metal and slag from being trapped in the weld metal during welding operations.
- (8) When flame cut edges are exposed, as in the flanges of fabricated members, care should be exercised to keep such edges smooth and even, and free from uneven hardnesses resulting from the flame cutting. It will be necessary that excessively hardened metal, sharp corners, and abrupt surface irregularities be removed from such edges.

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VIII APPENDIX SECTION A

SUMMARY OF TESTS

AND

TEST RESULTS

PLANS FOR CUTTING
SPECIMEN FROM PLATE
AND
EXHIBIT OF TESTS
PERFORMED ON EACH PLATE

PLAN FOLLOWED IN CUTTING SPECIMENS

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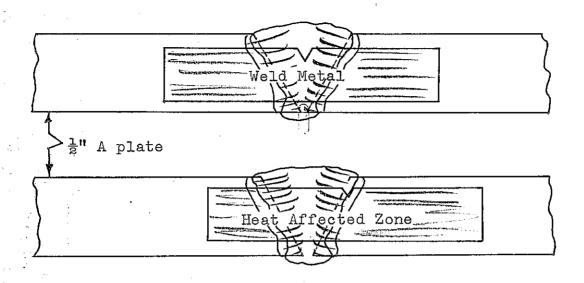
^{*} Extra Test Specimens for Proof Testing.

PLAN FOLLOWED IN CUTTING SPECIMENS

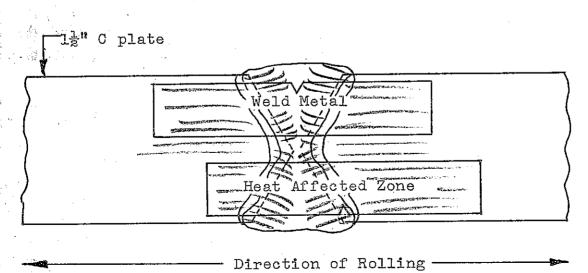
From 1" and 12" Carilloy T-1 Steel Test Plates

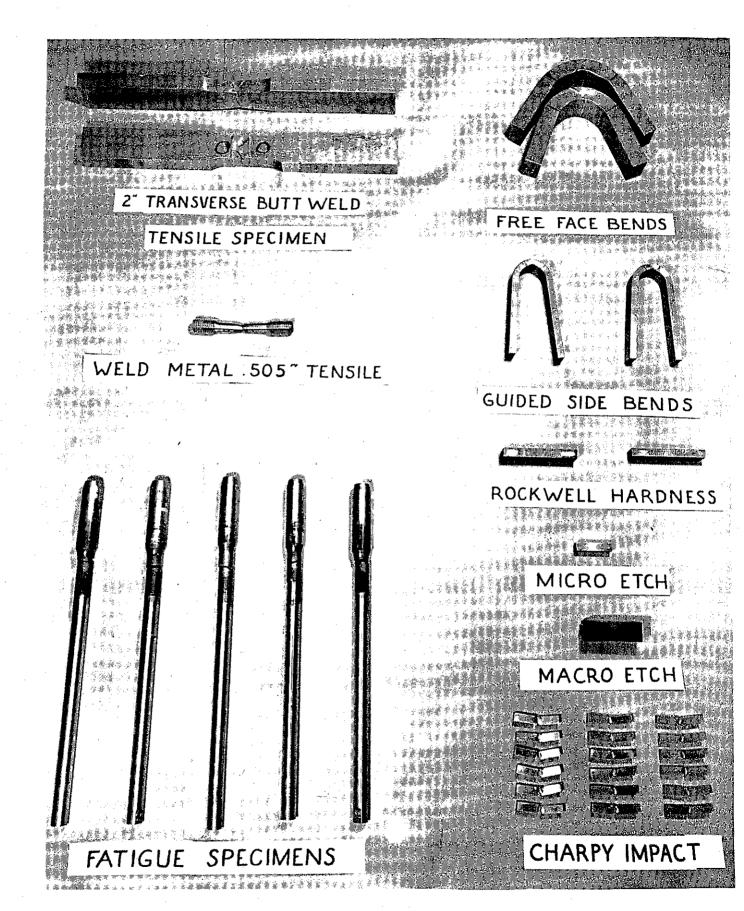
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LOCATION OF CHARPY V-NOTCH SPECIMENS AS TO WELD METAL AND HEAT AFFECTED ZONE









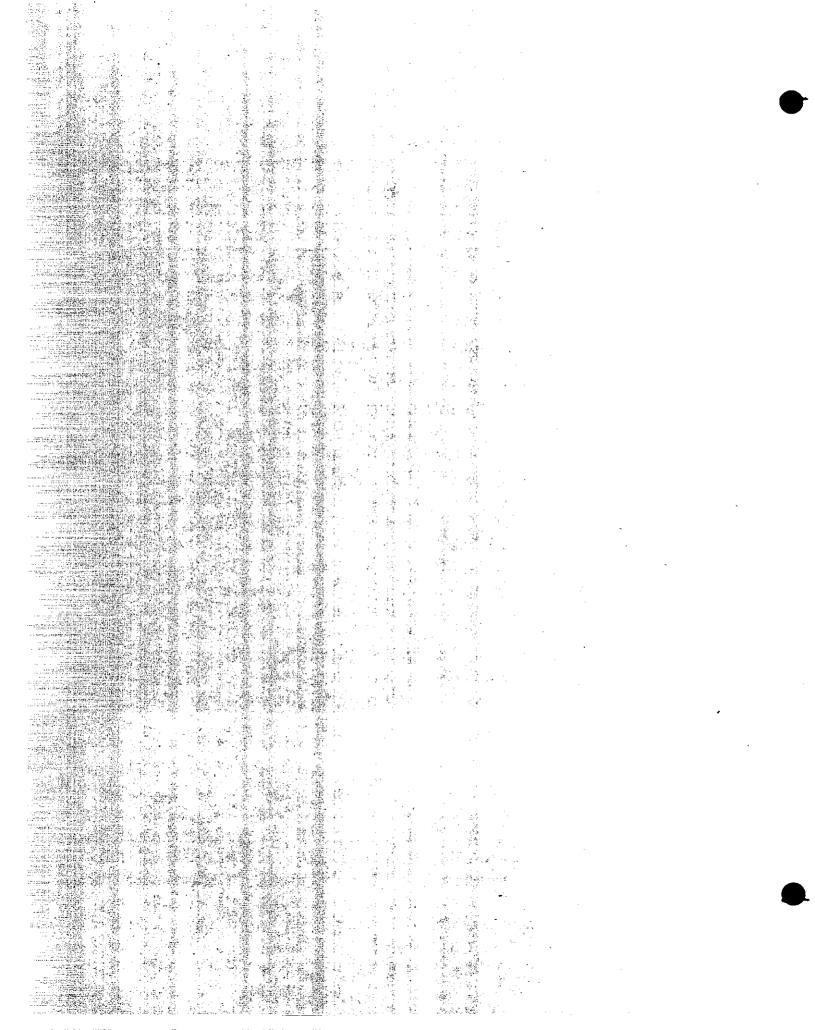
Picture of Test Specimens from each T-1 Sample Plate (no fatigue tests on $\frac{1}{2}$ " plate)

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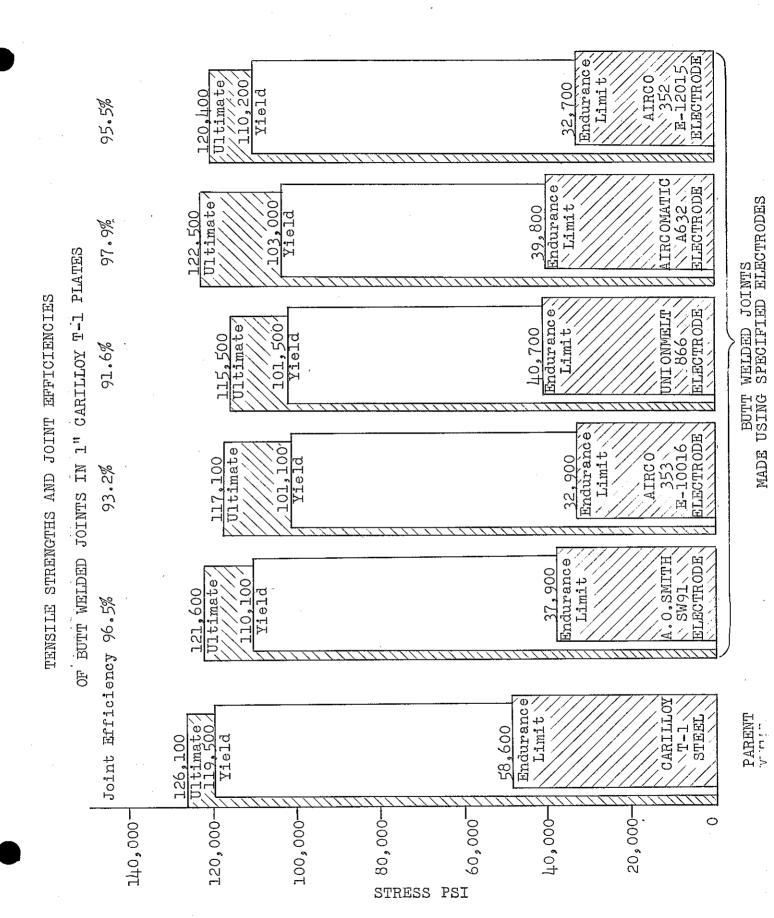
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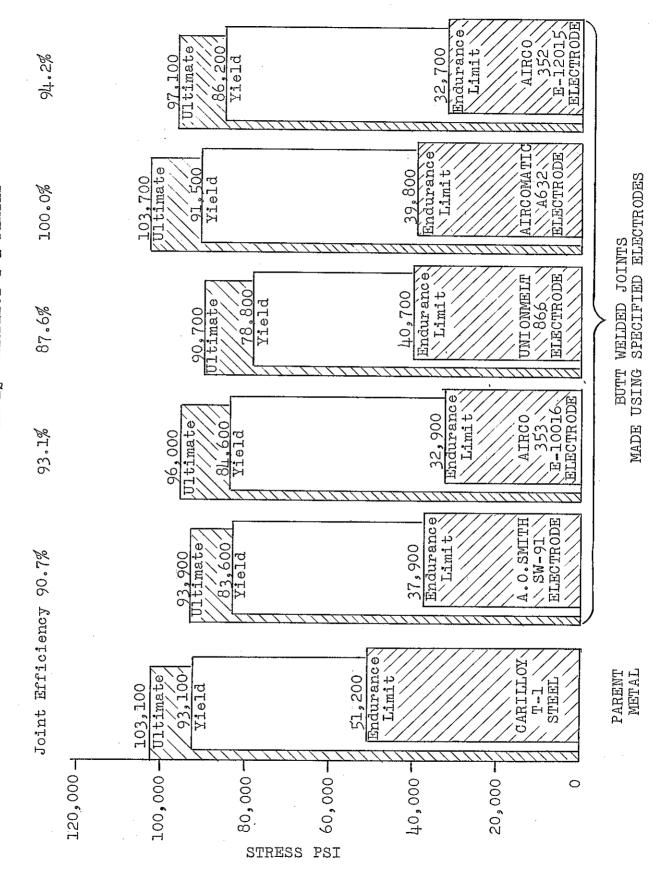
VARIOUS WELDS

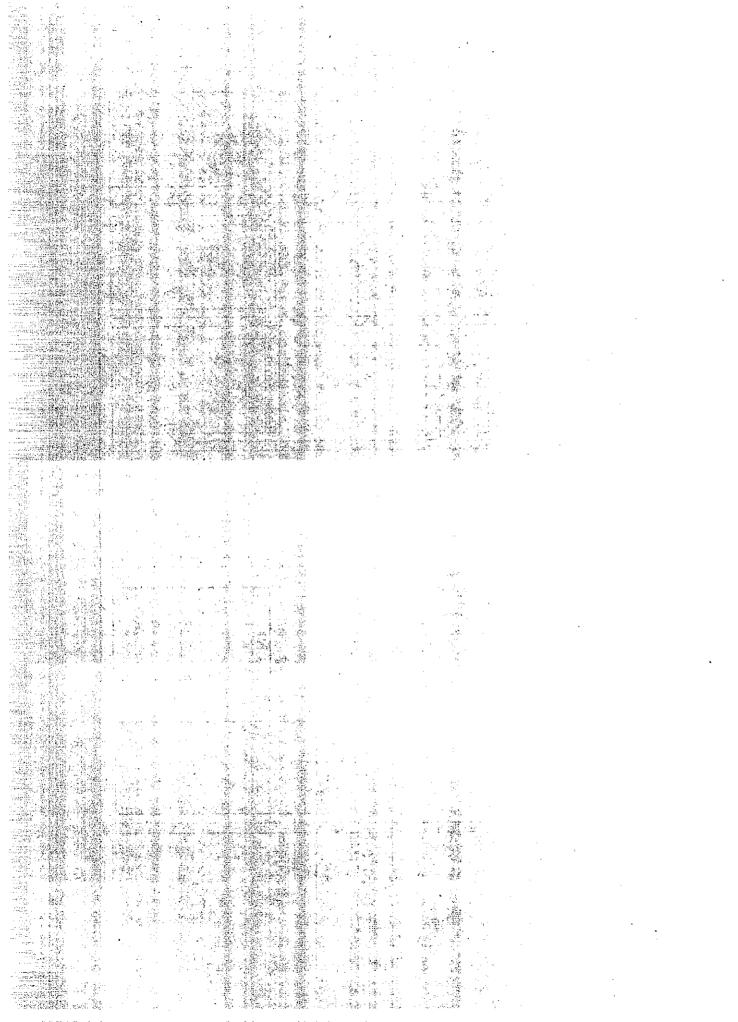


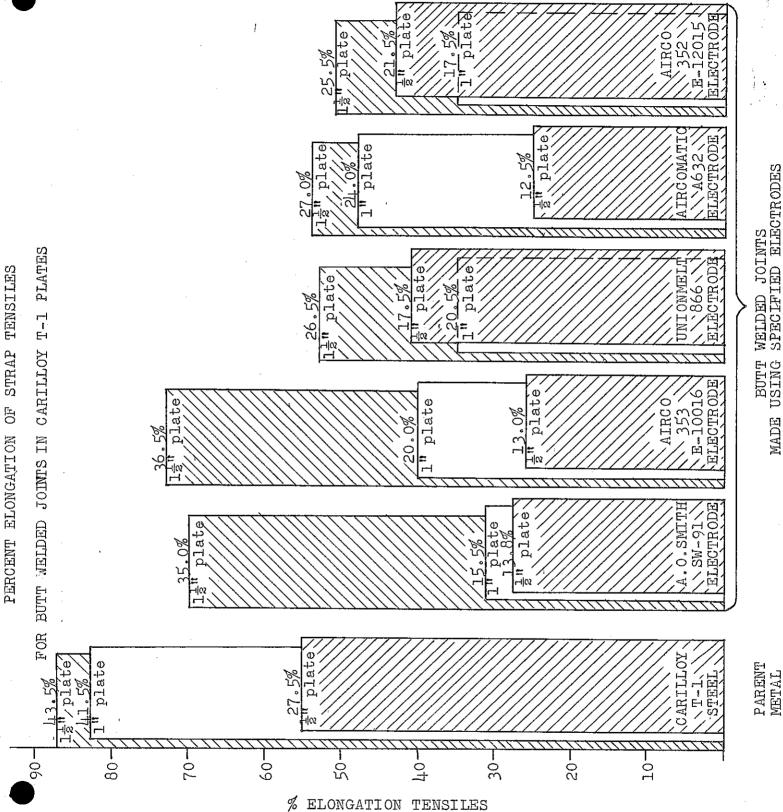
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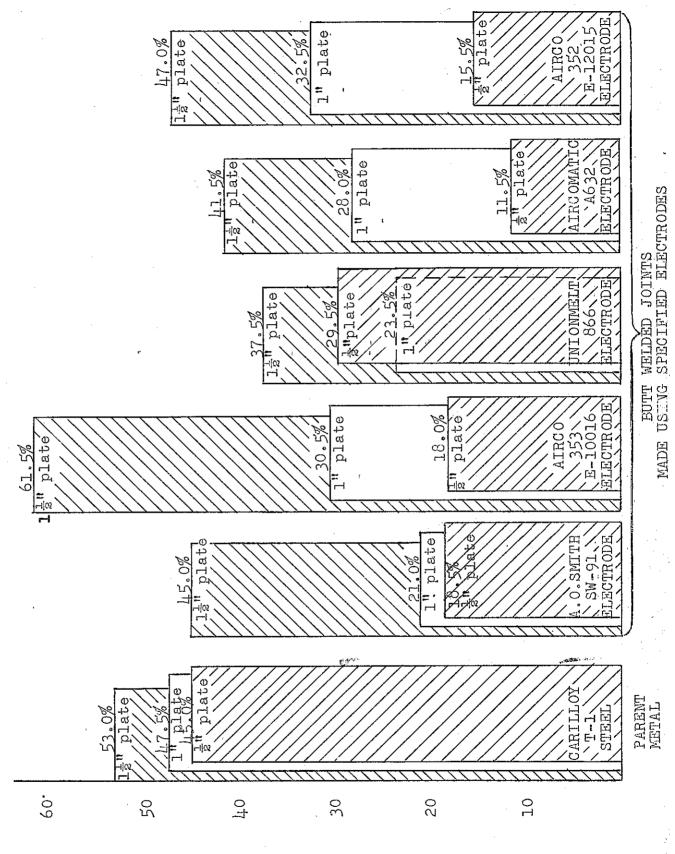


TENSILE STRENGTHS AND JOINT EFFICIENCIES OF BUIT WELDED JOINTS IN $1\frac{1}{2}$ " CARILLOY T-1 PLATES









FOR BUTT WELDED JOINTS IN CARILLOY T-1 PLATES

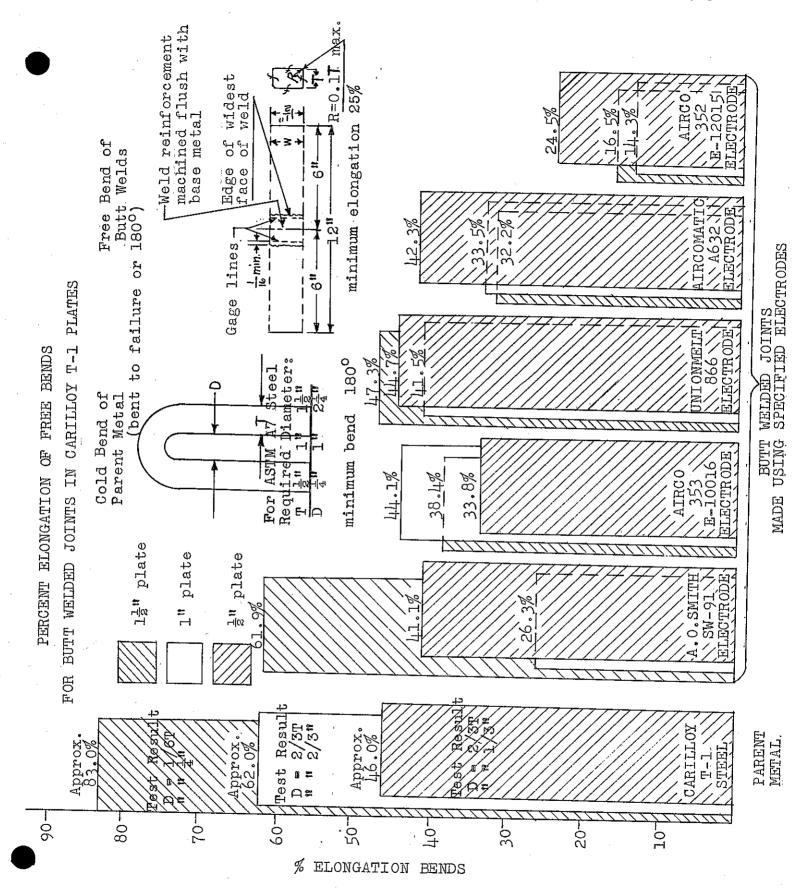
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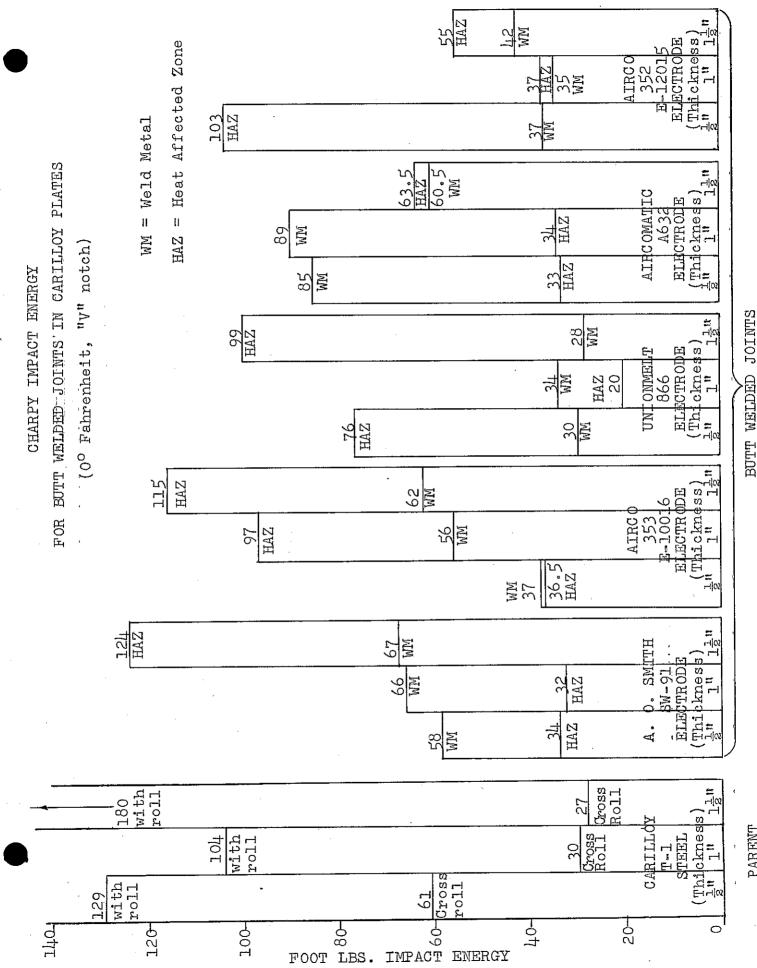
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	- - /" T-1 58,600 psi	T-1 math	Airco 352, E (2015, 32700 ps; Airco 353, E(00/6, 32,900 ps; 74-7, 30,800 ps;		STATE OF CALLFORMA MATERIALS & RESEARCH DEPARTMENT S-N DIAGRAM Carilloy "T," Steel in Welded Condition	ce in Single End r Testing Machine	6000 Cycles per. min. Date
					2000.	Apper 13° Another 11" Deep TEST SPECIMEN	2 3 4 5 6 7 8 9 105 2 3 4 5 6 7 8 9 105 C 1.
Nominal Stress, psi							

SUMMARY SHEETS OF RESULTS FOR

INDIVIDUAL TESTS

Sheet 1 Parent Metal and A.O. Smith Welds

Sheet 2 Airco 353 and Unionmelt Welds

Sheet 3 Aircomatic Welds

Sheet 4 Airco 352 Welds

VIII APPENDIX

SECTION B

PHOTOGRAPHS

OF

PHYSICAL TESTS

ON

T-1 STEEL

(Mill Test Report Included)

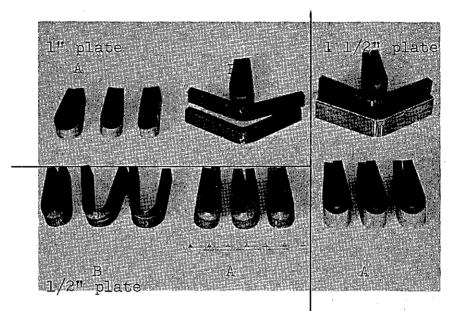
26.N-221-REV. 15.5

UNITED STATES STEEL CORPORATION

OPERATING DEPARTMENT—METALLURGICAL DIVISION

Exhibit 13 19 55G Bend Car Number INTERNATIONAL FRI. FORWARDING CO. Red. of Area % 63.4 8,69 72.6 Elong. 13 -2-04892-2/28-Dup. 112550 (31.5 11.8300 23.0 107300 24.0 FILE NO. Yack Rogal . Tensile Strength lips Roga sensie Affend in. Homestead "orks March 7, . 100100 108800 95780 Shipping Notice_ Test Piece Cut From 1-1/5 7/5 = Tempered DISTRICT .S.S.THI Steel Plates 91. 17. ß GR 2003 1.01 76. Boron-1002 Quenched & £84 V-*04 NO-448 Boron-1003 IN Pittsburgh 51 ಭ ಧ Boron S ANALYSIS .018 .018 4014 4018 M-15 •013 | •020 Test Spece JU- 36 V- di 120-12 V-•06 0.H. **37°** ₩. 48 8 8 14°88 P. - 24 Perma. Plates Report of CHEMICAL and PHYSICAL Tests of U 5 15 15 Same, Pittsburgh, 14,7682 1245年 150687 Slab No. U.S. Steel Co. 745022 67F599 **7457** Keat No. Mili Order No. UF-829 Charged to Shipped to Order No. and Date Customer's 1/3/55

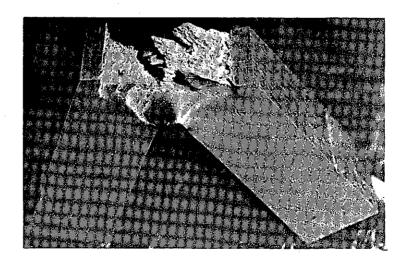
M.Brezin Chief We hereby certify that the above figures are correct as conficined in the records of the company



Cold bend tests of flame cut and machine cut edges. Note failure of flame cut edges. 1/2" plate was bent to side.

A - Machine cut

B - Flame cut



Note fibrous appearance of impact fracture typical of tough parent metal

CARILLOY T-1 STEEL

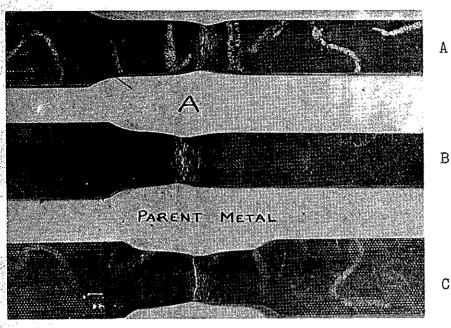
PHOTOGRAPHS

OF

TESTS

ON

1/2" PLATE

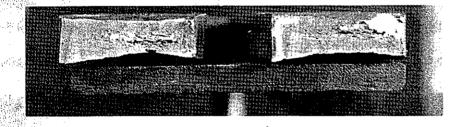


Parent Metal 8" and 2" Strap tensiles taken from 1/2" plate

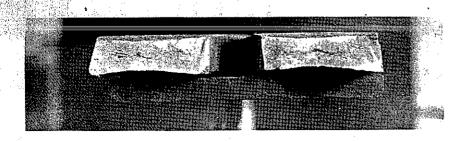
 \mathbb{B}

C

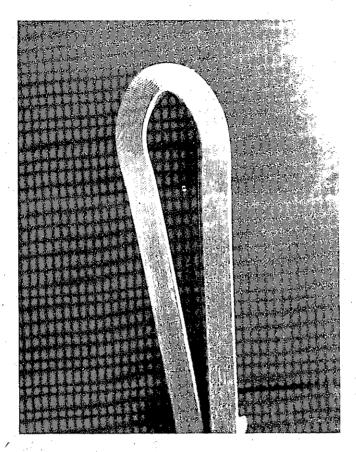
Yield	Ultimate	Elong. 11%@8"	<u>Red Area</u>
A 116,300psi	127,200psi	11%@8**	45%
B 118,300psi	130,800psi	9.5%@8"	42%
C 125,600psi	132,700psi	27.5%@2"	48%



End View of Parent Metal Tensile Failure 1/2" plate

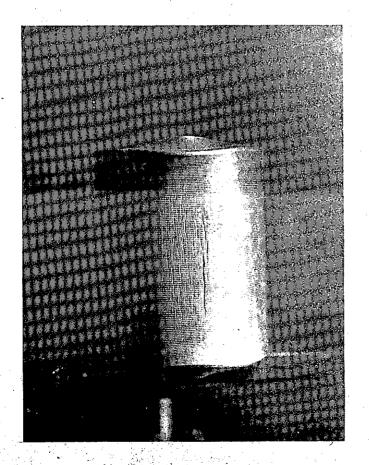


End View of Parent Metal Tensile Failure 1/2" plate



Cold bend test 1/2" Carilloy T-1 plate

Side view



.

Note openings in bend face

Face view

CARILLOY T-1 STEEL

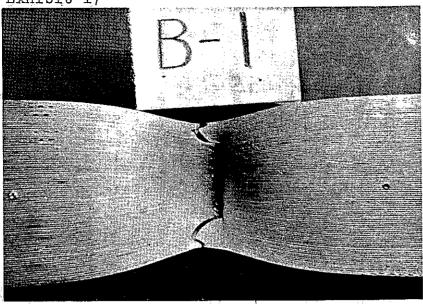
PHOTOGRAPHS

OF

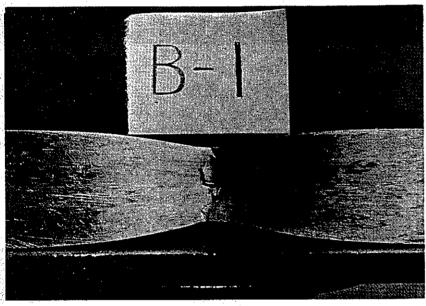
TESTS

ON

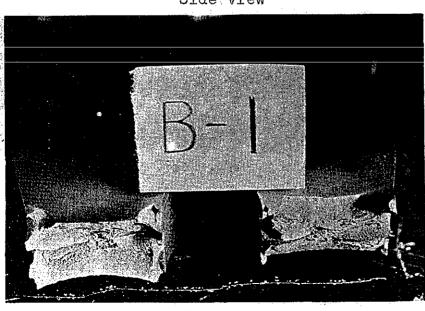
l" PLATE



Face view



Side view

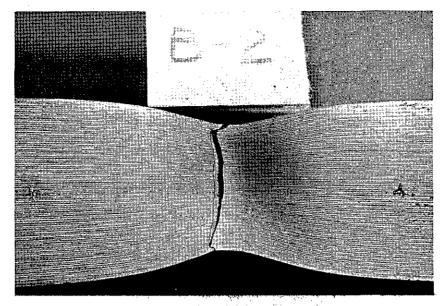


End view

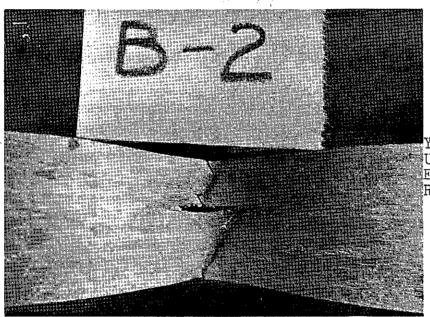
2" strap tensile from 1" Carilloy T-1 plate

Note parallel shear in ductile fracture

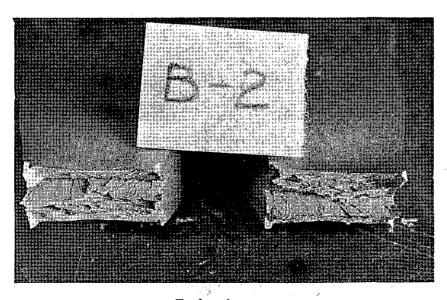
Yield Strength 116,100 Ultimate " 122,800 Elongation 41%2" Red Area 57%



Face view



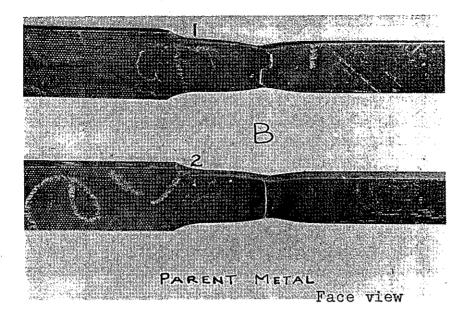
Side view



End view

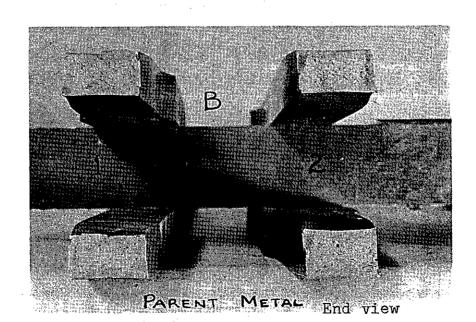
2" strap tensile from
1" Carilloy T-1 plate
(note parallel shear
in ductile fracture)

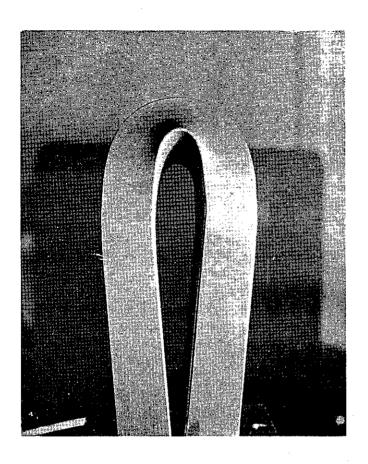
Yield Strength 114,500psi Ultimate " 123,400psi Elongation 42%@2" Red Area 58%



8" strap tensile specimens from 1" plate (note rolling structure visible in these fractures)

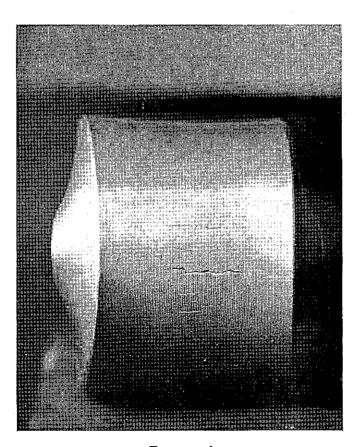
	Yield Strength	Ultimate Strength	%2" Elongation	Red Area
1.	123,000psi	127,600psi	11.%	37%
2	120,300psi	128,100psi	11.5%	38%





Cold bend test
l" Carilloy T-l plate

Side view



Face view

Note openings in bend face

CARILLOY T-1 STEEL

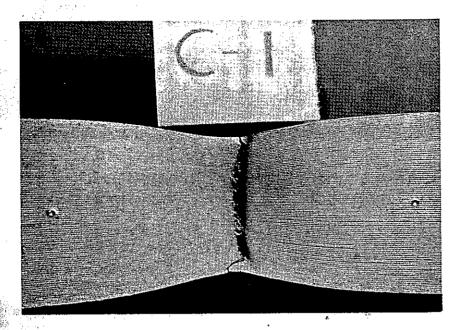
PHOTOGRAPHS

OF

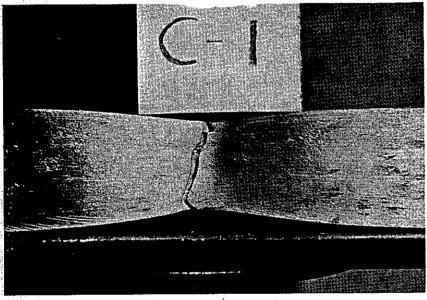
TESTS

ON

1 1/2" PLATE



Face view



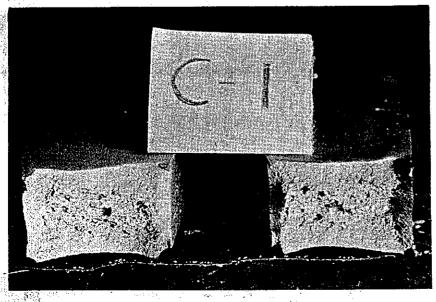
2" strap tensile 1 1/2" Carilloy T-1 plate

Yield 90,000psi Ultimate 100,300psi

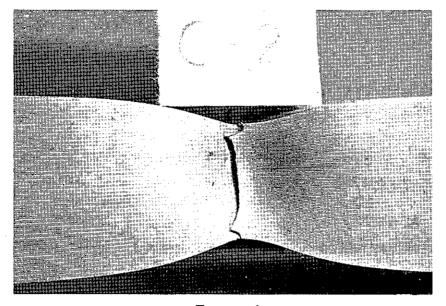
Elongation 39%@2"

Red Area 49%

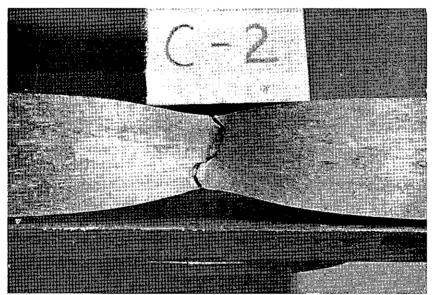
Side view



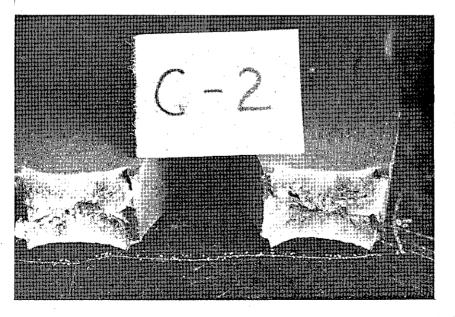
End view Note rolling structure



Face view



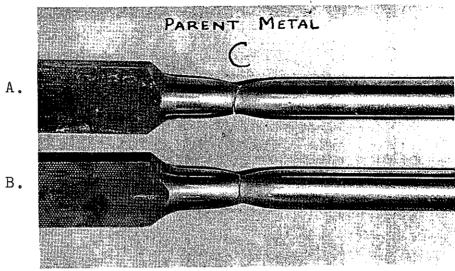
Side view



End view (note shear)

2" strap tensile from 1 1/2" Carilloy T-1 plate

Yield Strength 90,600psi Ultimate " 102,800psi Elongation 48%2" Red Area 61%

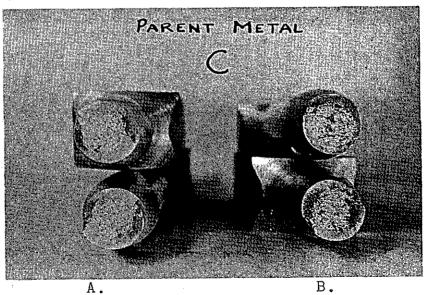


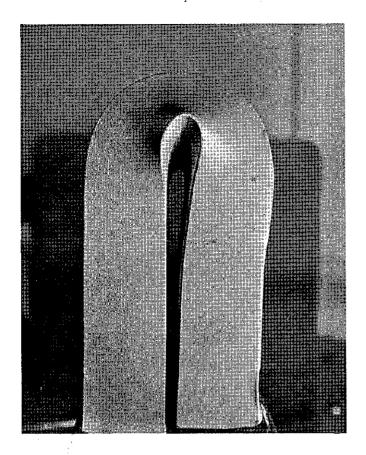
Side view

8" bar tensile from 1 1/2" plate

	Yield Strength	Ultimate <u>Strength</u>	8" % Elongation	% Red <u>Area</u>
A.	96,000psi	106,000psi	14%	50%
В.	97,500psi	106,100psi	14%	53%

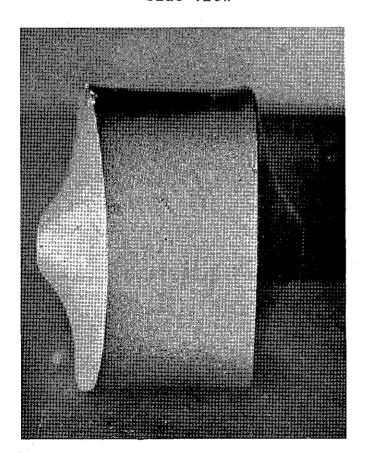
End view





Cold bend test 1 1/2" Carilloy T-1 plate

Side view



Face view

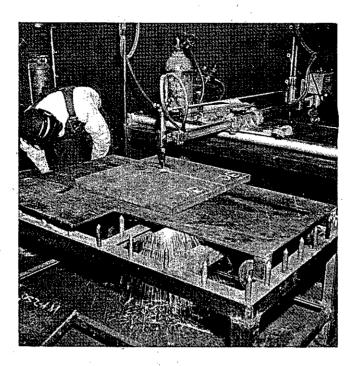
VIII APPENDIX SECTION C

THE

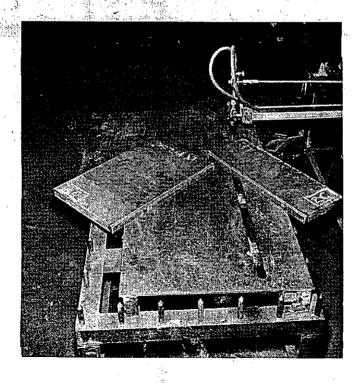
FLAME CUTTING AND BEVELING

OF

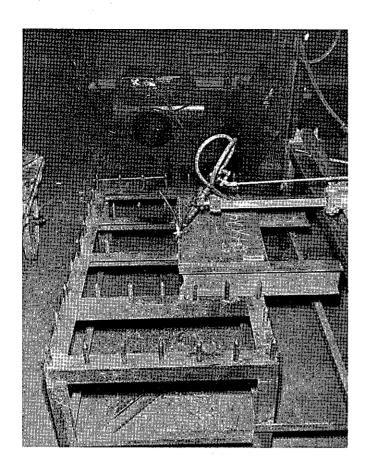
T-1 STEEL PLATE



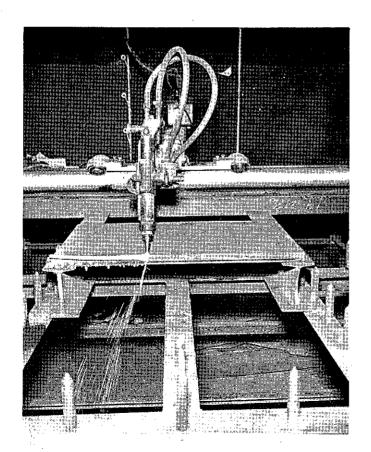
The Carilloy T-l test plates were flame-cut with an Airco automatic cutting machine as shown here in operation on the $1\ 1/2^m$ plates



The first cut was made at 90° to the plate surface as illustrated at left and above



The flame cut edges were beveled to 30° in the second operation on the plate as illustrated at left and below



Front view of the Oxyacetylene beveling on the
1 1/2" thick test plate.
Settings of oxygen pressure,
speed of cutting, in inches
per minute, and size of
cutting tip were as recomended by the manufacturer for
this cutting equipment

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1/2" plate

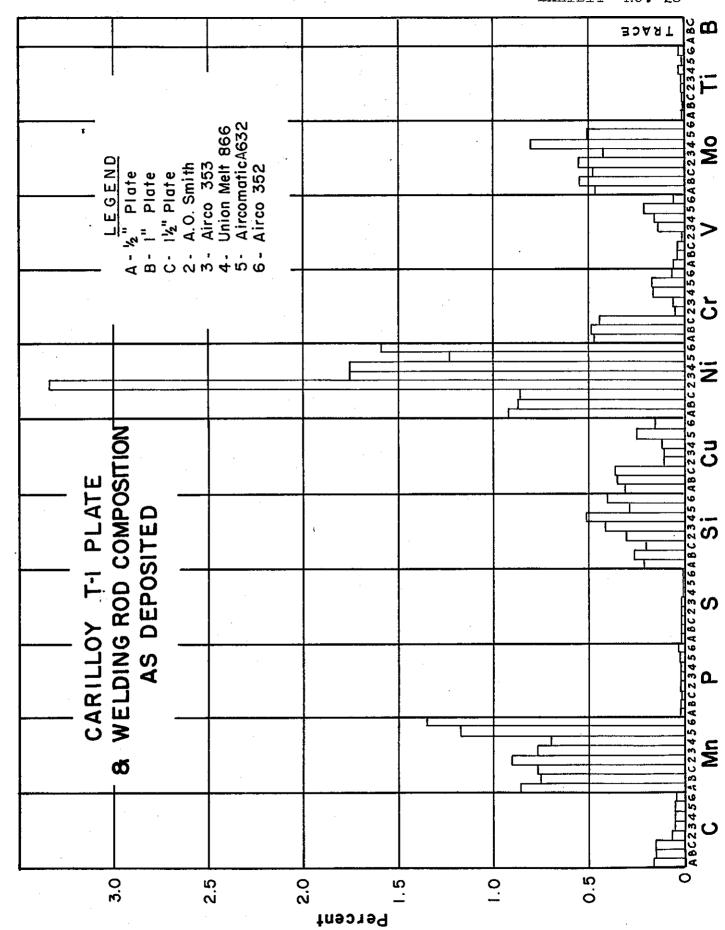
ができる。 のでは、 のでは

l" plate

1-1/2" plate

Welds listed by number from top to bottom are as follows.

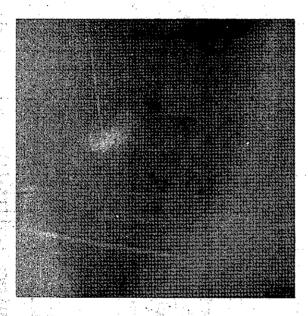
- 6. Airco manual low hydrogen using 352 (El2015) electrodes.
- 5. Aircomatic semi-automatic inert gas shielded arc using a 98% argon 2% oxygen shield with A632 electrode wire.
- 4. Unionmelt, automatic, submerged arc, using #80 flux with #866 electrode wire. (Oxweld wire)
- 3. Airco manual low hydrogen using 353 (E10016) electrodes.
- 2. A. O. Smith manual low hydrogen using SW 91 (EllO16 tentative) electrodes.



MANUAL WELDING



The manual welds were prepared by a State certified journeyman welder using a downhand position as shown here.



Here can be seen the electrode tilt angle used in manually welding the 1 1/2" thick Carilloy T-1 test plate.



The finished weld test plate is seen here. The temperature from welding on the test plate was not allowed to exceed 400°F inter-pass temp.

MANUAL WELDING

DETAILS

OF

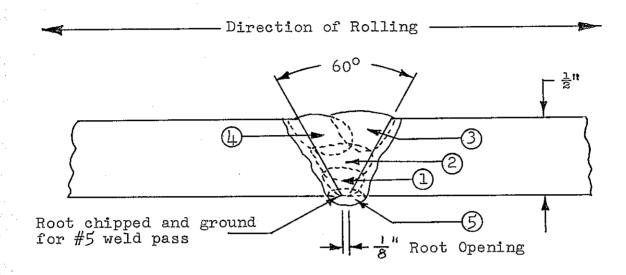
BUTT WELDED JOINTS

USING

A. O. SMITH

s. W. 91, LOW HYDROGEN ELECTRODES (E-11016 TENTATIVE)

DETAILS OF STANDARD BUTT WELD FOR THE CARILLOY T-1 ** Steel Plate No. 2A



Type of Welding Process - Manual

No. of Passes - 5

Electrode - A. O. Smith No. SW-91 low hydrogen

Electrode Diameter 5/32" and 3/16"

Current - Direct

Polarity - Reverse

Amperes - 150 to 230

Arc-volts 25 ±

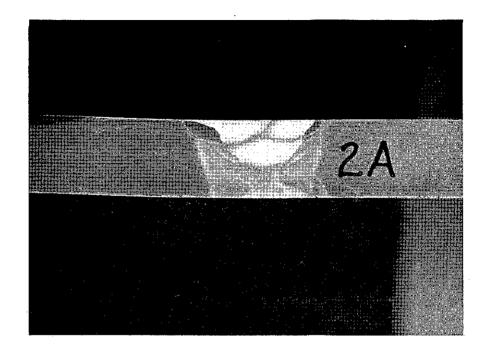
Average Welding Speed of Travel - $4\frac{1}{2}$ " per min.

Starting Plate Temp. 70°F to 75°F

Finish Plate Temp. Welding Area - 400°F

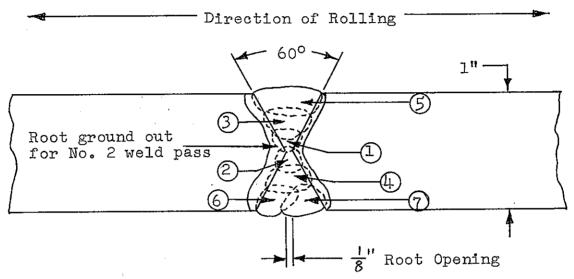
Normal Cool Down to Room Temp.

Note: Passes No. 1 and 5 were welded with 5/32" diameter electrode.



Cross section of 1/2" butt joint manually welded using A. O. Smith SW 91 (E-11016 tentative) electrodes.

DETAILS OF STANDARD BUTT WELD FOR CARILLOY T-1 1" Steel Plate No. 2B



Type of Welding Process - Manual

No. of Passes - 7

Electrode Type - A. O. Smith No. SW 91 low hydrogen

Electrode Diameter - 5/32" and 3/16"

Current - Direct

Polarity - Reverse

Amperes - 160 - 240

Arc-volts 25 ±

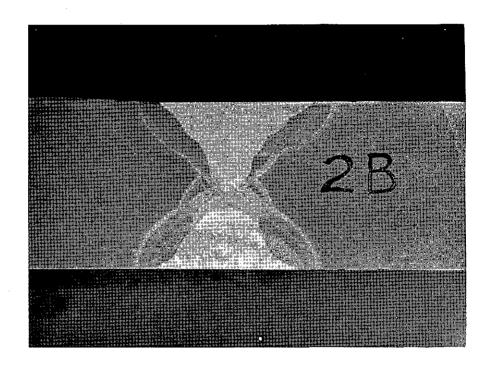
Average Welding Speed of Travel - 4" per min.

Starting Plate Temp. $70^{\circ}F$ to $75^{\circ}F$

Finish Plate Temp. - Welding Area 400°F

Normal Cool Down to Room Temp.

Note: Weld passes No. 1 and 2 were welded with 5/32" diameter electrode.

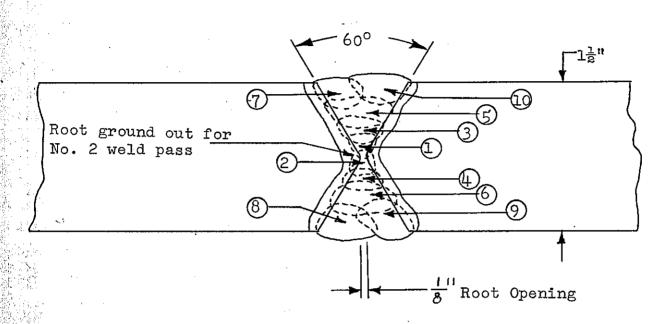


Cross-Section of 1" butt joint manually welded using A. O. Smith SW 91 (Ell016 tentative) electrodes.



DETAILS OF STANDARD BUTT WELD FOR THE CARILLOY T-1 $\frac{1}{2}$ " Steel Plate No. 2C

Direction of Rolling



Type of Welding Process - Manual

No. of Passes - 10

Electrode Type - A. O. Smith No. SW91 low hydrogen

Electrode Diameter - 5/32" and 3/16"

Current - Direct

Polarity - Reverse

Amperes - 160 - 240

Arc-volts 25 ±

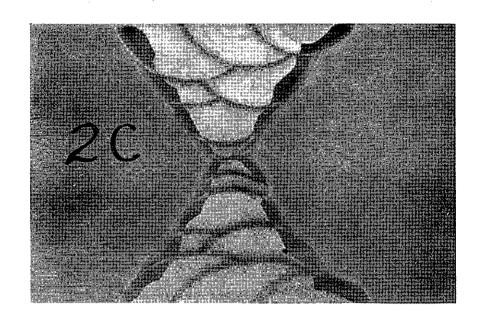
Average Welding Speed of Travel - 31 per min.

Starting Plate Temp. 70°F to 75°F

Finish Plate Temp. - Welding Area 400°F

Normal Cool Down to Room Temp.

Note: Weld passes No. 1 and 2 welded with 5/32" diameter electrodes.



Cross-section of 1 1/2" butt joint manually welded using A. O. Smith SW 91 (EllOl6 tentative) electrodes.

MANUAL WELDING

DETAILS

OF

BUTT WELDED JOINTS

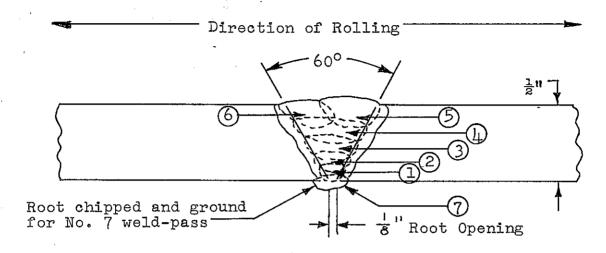
USING

AIRCO

353, LOW HYDROGEN ELECTRODES

(E-10016)

DETAIL OF STANDARD BUTT WELD FOR CARILLOY T-1 2 Steel Plate No. 3A



Type of Welding Process - Manual

No. of Passes - 7

Electrode - Airco No. 353-El0016 low hydrogen

Electrode Diameter - 5/32"

Current - Direct

Polarity - Reverse

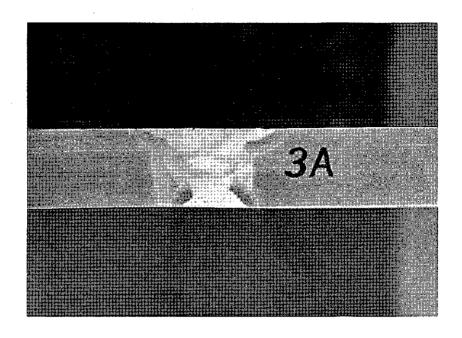
Amperes - 140 to 160

Arc-volts 24 +

Average Welding Speed of Travel - 5th per min.

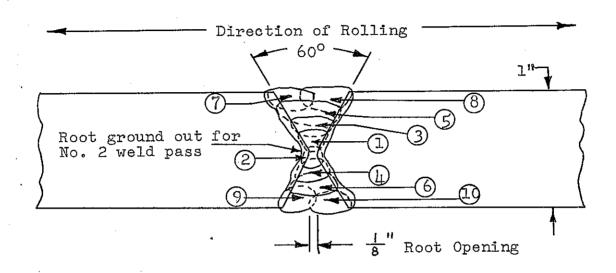
Starting Plate Temp. 70°F to 75°F

Finish Plate Temp. - Welding Area 400°F



Cross-section of 1/2" butt joint manually welded using Airco 353 E-10016 electrodes.

DETAILS OF STANDARD BUTT WELD FOR CARILLOY T-1 1" Steel Plate No. 3B



Type of Welding Process - Manual

No. of Passes - 10

Electrode Type - Airco 353 - El0016 low hydrogen

Electrode Diameter - 5/32"

Current - Direct

Polarity - Reverse

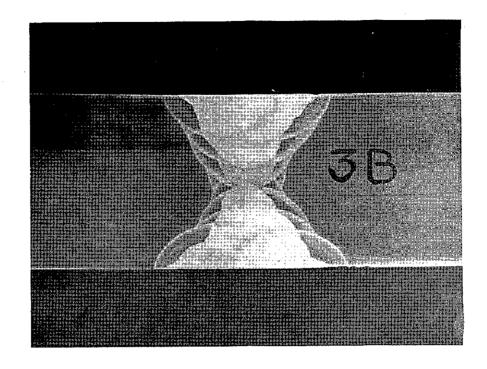
Amperes - 150 to 170

Arc-volts 20 ±

Average Welding Speed of Travel - 5" per min.

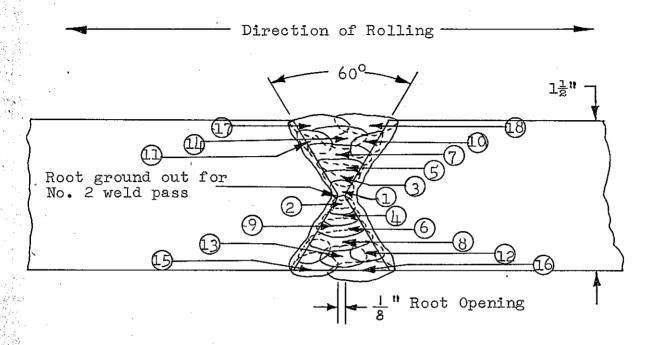
Starting Plate Temp. 70°F to 75°F

Finish Plate Temp. $400^{\circ}F$



Cross-section of 1" butt joint manually welded using Airco 353 E-10016 electrodes.

DETAILS OF STANDARD BUTT WELD FOR THE CARILLOY T-1 $1\frac{1}{2}$ " Steel Plate No. 3C



Type of Welding Process - Manual

No. of Passes - 18

Electrode Type - Airco 353 El0016 low hydrogen

Electrode Diameter - 5/32"

Current - Direct

Polarity - Reverse

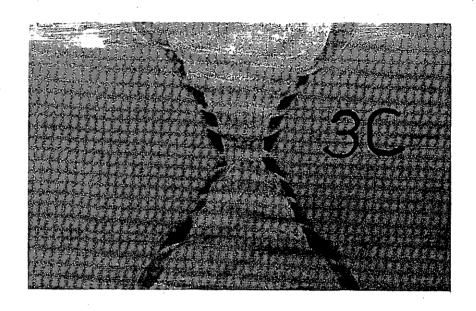
Amperes - 160 to 170

Arc-volts 20+

Average Welding Speed of Travel - 4" per min.

Starting Plate Temp. 70°F to 75°F

Finish Plate Temp. 350°F



Cross-section of 1 1/2" butt joint manually welded using Airco 353 E-10016 electrodes.

MANUAL WELDING

DETAILS

OF

BUTT WELDED JOINTS

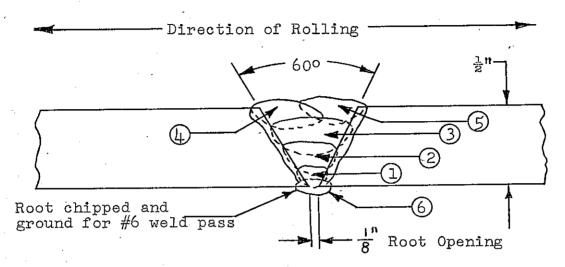
USING

AIRCO

352, LOW HYDROGEN ELECTRODES

(E-12015)

DETAILS OF STANDARD BUTT WELD FOR THE CARILLOY T-1



Type of Welding Process - Manual

No. of Passes - 6

Electrode Type - Airco #352 - El2015 low hydrogen

Electrode Diameter 5/32"

Current - Direct

Polarity - Reverse

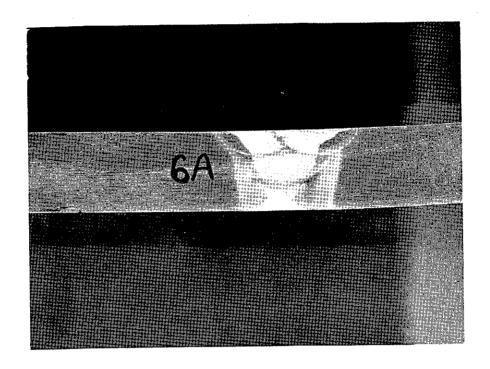
Amperes - 140 to 160

Arc-volts 24 +

Average Welding Speed of Travel - 5" per min.

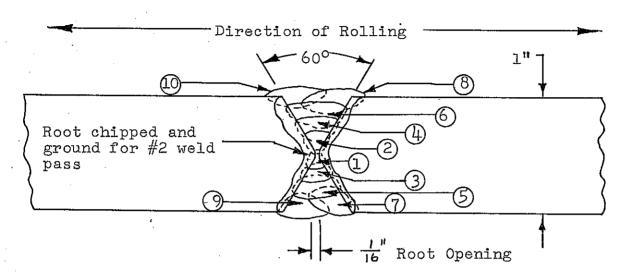
Starting Plate Temp. 70°F to 75°F

Finish Plate Temp. - Welding Area - 400°F



Cross-section of 1/2" butt joint manually welded using Airco 352 E-12015 electrodes.

DETAILS OF STANDARD BUTT WELD FOR CARILLOY T-1 1" Steel Plate No. 6B



Type of Welding Process - Manual

No. of Passes - 10

Electrode Type - Airco #352 - El2015 low hydrogen

Electrode Diameter - 5/32" and 3/16"

Current - Direct

Polarity - Reverse

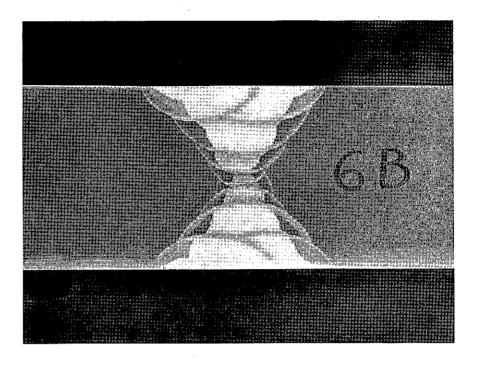
Amperes - 160 to 220

Arc-volts 24 +

Average Welding Speed of Travel 5th per min.

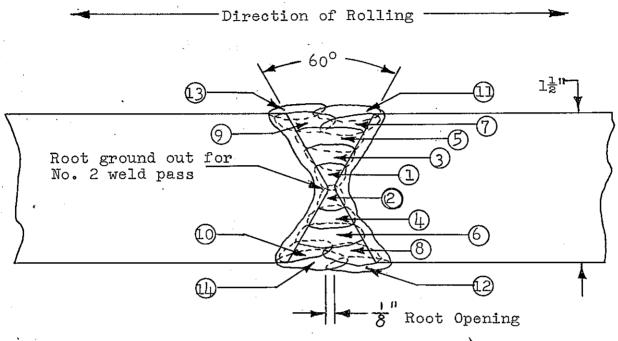
Starting Plate Temp. 70°F to 75°F

Finish Plate Temp. 400°F



Cross-section of 1" butt joint manually welded using Airco 352 E-12015 electrodes.

DETAILS OF STANDARD BUTT WELD FOR THE CARILLOY T-1 12" Steel Plate No. 6C



Type of Welding Process - Manual

No. of Passes - 14

Electrode Type - Airco No. 352 - El2015 - low hydrogen

Electrode Diameter - 5/32" and 3/16"

Current - Direct

Polarity - Reverse

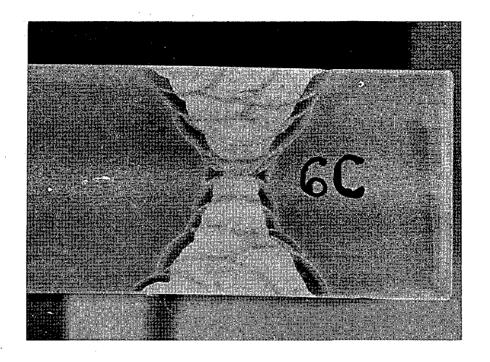
Amperes - 150 to 220

Arc-volts 24 +

Average Welding Speed of Travel 5" per min.

Starting Plate Temp. 70°F to 75°F

Finish Plate Temp. $400^{\circ}F$



Cross-section of 1 1/2" butt joint manually welded using Airco 352 E-12015 electrodes.

AUTOMATIC WELDING

DETAILS

of

BUTT WELDED JOINTS

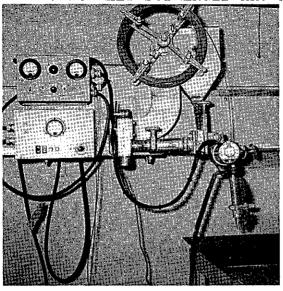
USING

UNIONMELT SUBMERGED ARC PROCESS

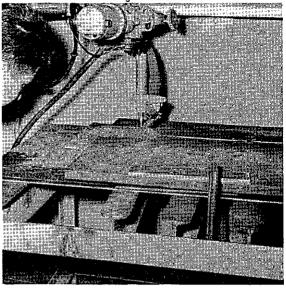
WITH

OXWELD 866 ELECTRODE WIRE AND 80 FLUX

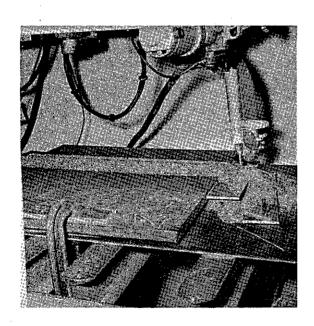
UNIONMELT SUBMERGED-ARC AUTOMATIC WELDING EQUIPMENT



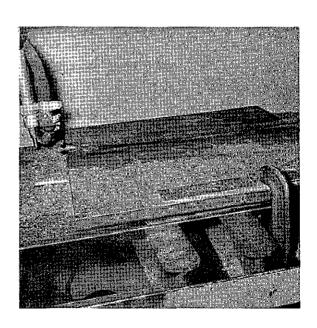
Seen above are the current regulator, the wire feed, and the flux bin.



Note the flux feed covering the arc during the pass.

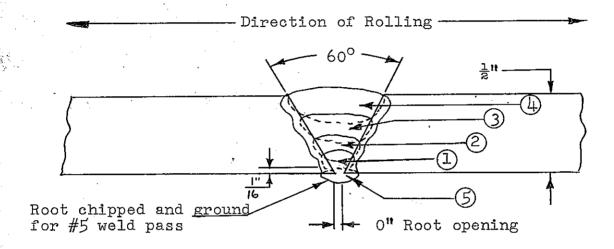


The Completed Pass



Note the flux peeling off the weld

DETAILS OF STANDARD BUTT WELD FOR THE CARILLOY T-1



Type of Welding Process - Submerged Arc - Linde Air - Unionmelt
No. of Passes - 5

Flux - Composition Grade No. 80 - 12 x 65 - Unionmelt

Electrode Type - 866 Oxweld

Electrode Diameter - 1/8"

Current - Direct

Polarity - Reverse

Amperes - 350 to 450

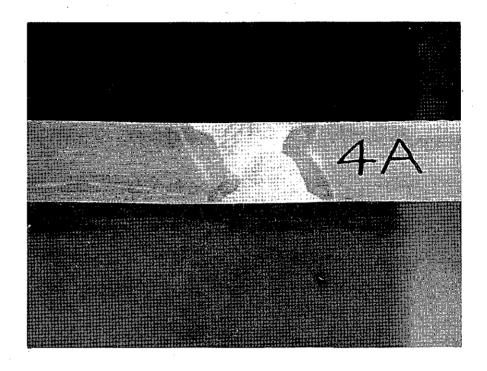
Arc-Volts $28\pm$ 2 to 30 \pm 2 volts

Average Welding Speed of Travel 14" per min.

Starting Plate Temp. $70^{\circ}F$ to $75^{\circ}F$

Finish Plate Temp. - Welding Area - 400°F

Normal Cool Down to Room Temp.



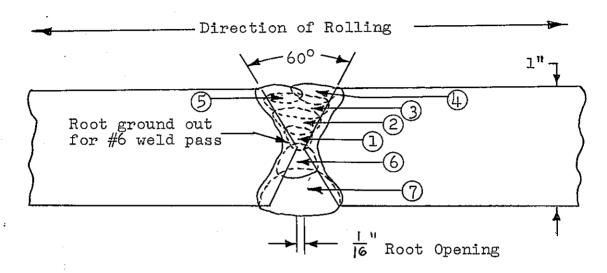
Cross-section of 1/2" butt joint automatically welded using the Unionmelt submerged-arc process.

Welding pass detail for the weld as follows:

Pass	In/Min	Volts	Amps
1	22	28	350
2	18	30	350
3 ^^	14	30	350
4	14	30	450
*5	14	30	450

*Note: The No. 5 pass was welded after backgrinding down to the #1 pass with a disc sander in order to insure complete penetration.

DETAILS OF STANDARD BUTT WELD FOR CARILLOY T-1 1" Steel Plate No. 4B



Type of Welding Process - Submerged Arc - Linde Air, Unionmelt

No. of Passes - 7

Flux Composition - Grade 80 - 12 x 65 - Unionmelt

Electrode Type - 866 Oxweld

Electrode Diameter - 1/8"

Current - Direct

Polarity - Reverse

Amperes - 450 to 550

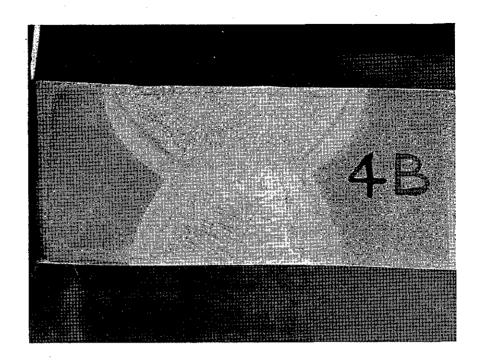
Arc-volts 30 ± 2 volts

Average Welding Speed of Travel - 12th per min.

Starting Plate Temp. 70°F to 75°F

Finish Plate Temp. 400°F

Normal Cool Down to Room Temp.

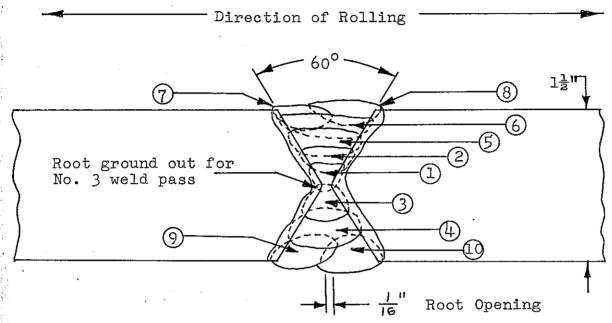


Cross-section of l" butt joint automatically welded using the Unionmelt submerged-arc process.

Welding pass detail for the weld as follows:

Pass	In/Min	Volts	Amps
1	22	29/31	450
2 .	18	29/31	500
3	14	29/30	550
4	12	29/30	550
5	12	29/30	550
6	10	29/31	550
7	10	29/31	550

DETAILS OF STANDARD BUTT WELD FOR THE CARILLOY T-1 12" Steel Plate No. 4C



Type of Welding Process - Submerged arc - Linde Air - Unionmelt

No. of Passes - 10

Flux - Composition - Grade 80 - 12 x 65 Unionmelt

Electrode Type - 866 Oxweld

Electrode Diameter - 1/8"

Current - Direct

Polarity - Reverse

Amperes - 430 to 550

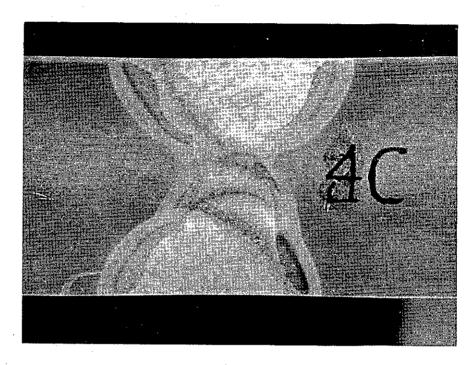
Arc-volts 30 ± 2 volts

Average Welding Speed of Travel - 10" and 14" per min.

Starting Plate Temp. 70°F to 75°F

Finish Plate Temp. 400°F

Normal Cool Down to Room Temp.



Cross-section of 1 1/2" butt joint automatically welded using the Unionmelt submerged-arc process

Welding pass detail for the weld as follows:

Pass	In/Min	Volts	Amps
1	18	29/30	430
2	14	29/30	430
3	14	29/30	500
4	10	29/30	550
5	10	29/30	550
6	10	29/30	550
7	10	29/30	550
8	10	29/30	550
9	10	29/30	550
10	10	29/30	550

SEMI-AUTOMATIC WELDING

DETAILS

OF

BUTT WELDED JOINTS

USING

AIRCOMATIC INERT GAS SHIELDED ARC PROCESS

WITH

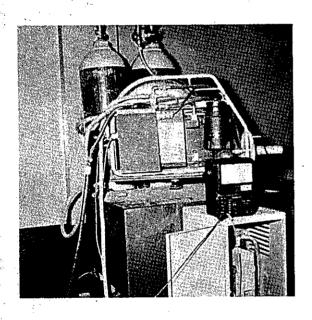
A632 ELECTRODE WIRE AND A 98%A - 2%O₂ SHIELD

AIRCOMATIC INERT GAS SHIELDED ARC SEMI-AUTOMATIC WELDING

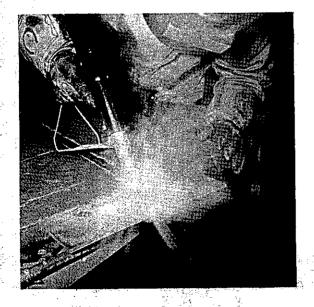
EQUIPMENT

D.C. QUARTERE CECCO CECO CECCO CECO CECCO CECO CECCO CECCO CECCO CECCO CECCO CECCO CECCO CECCO CECO

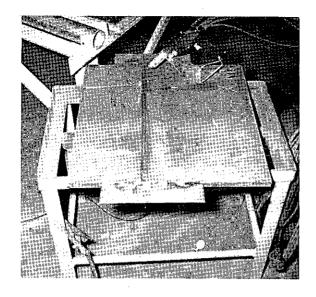
The power supply, Airco D.C. Bumblebee, used for the Aircomatic welding process. The test plates No. 5A-5B-5C.



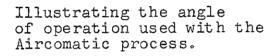
Gas and wire feed control unit for the Aircomatic welding process.

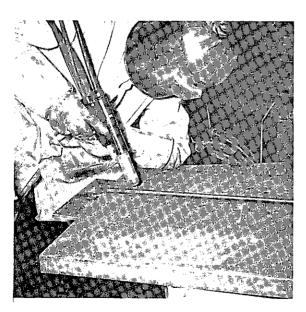


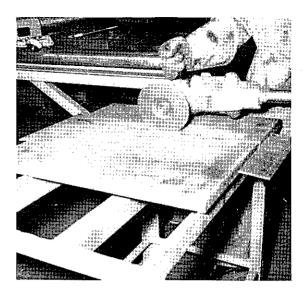
This is the manual operating position for the type 21 Aircomatic gun used semi-automatically.



The first weld pass here put in with manually operated Aircomatic welding on the l" thick test plate 5B.

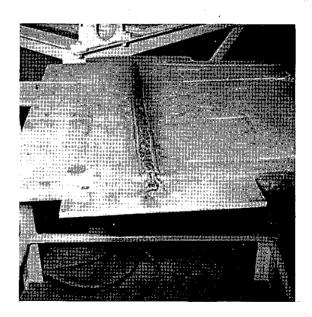




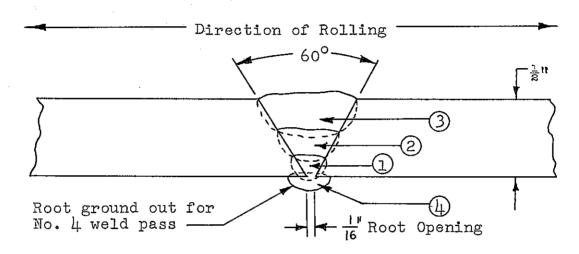


A disc sander was used to grind down the first weld pass to insure complete penetration of the 2nd weld pass, on the side opposite the 1st weld pass.

The finished Aircomatic weld on test plate 5C.



DETAILS OF STANDARD BUTT WELD FOR THE CARILLOY T-1 2" Steel Plate No. 5A



Type of Welding Process - Aircomatic No. 21 Gun Gas Shield No. of Passes - 4

Electrode Type - A632 - Alloy No. 2

Gas Flow - Low Side 30/CFH

Gas Shield - Argon (No. 2) 98% Argon (2% 02)

Electrode Diameter - 1/16"

Electrode Wire Feed 240 inches per min.

Current - Direct

Polarity - Reverse

Amperes - 360

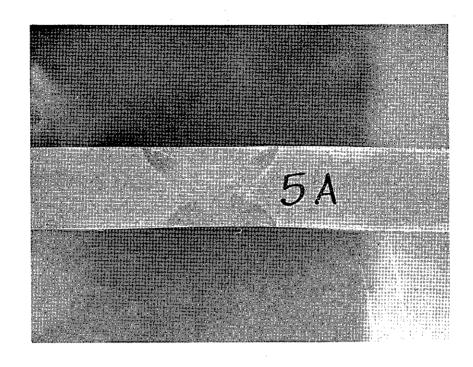
Arc-volts 30 ± 2 volts

Average Welding Speed of Travel 12 and 16" per min.

Starting Plate Temp. 70°F to 75°F

Finish Plate Temp. - Welding Area 400°F

Normal Cool Down to Room Temp.



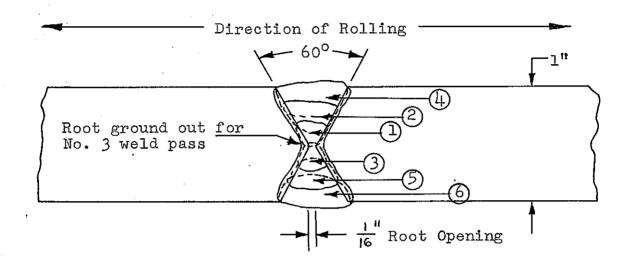
Cross-section of 1/2" butt joint semi-auto matically welded using the Aircomatic inert gas shielded arc process with A632 electrode wire.

Welding pass detail for the welds are as follows:

Pass no.	Amps.	Volts	wire feed per/min	Gas Flow	Inches Per Min
1	360 _.	30/31	240	30/CFH	20
2	360	30/31	240	30/CFH	16
3	360	31/33	240	30/cFH	12
4	360	31/32	240	30/CFH	16

The no. 4 pass was welded after back grinding down to the No. 1 weld pass with a disc sander in order to insure complete penetration.

DETAILS OF STANDARD BUTT WELD FOR CARILLOY T-1 1" Steel Plate No. 5B



Type of Welding Process - Aircomatic: No. 21 gun, Gas Shield No. of Passes - 6

Electrode Type - A632 Alloy No. 2

Electrode Diameter 1/16"

Gas Shield - Argon (No. 2) - 98% Argon (2% 02)

Gas Flow - Low Side - 30/CFH

Current - Direct

Polarity - Reverse

Amperes - 365

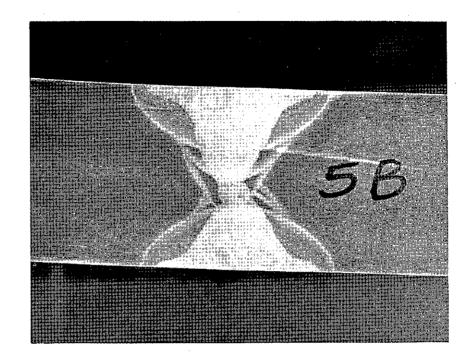
Arc-volts 30 \pm 2 volts

Average Welding Speed of Travel - 12" per min.

Starting Plate Temp. $70^{\circ}F$ to $75^{\circ}F$

Finish Plate Temp. 400°F

Normal Cool Down to Room Temp.

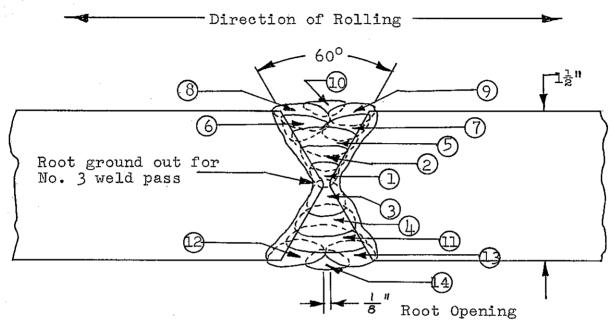


Cross-section of a l" butt joint semiautomatically welded using the Aircomatic inert gas shielded arc process with A632 electrode wire.

Welding pass detail for the welds are as follows:

Pass No.	Amp.	Volts.	Wire feed Per/min	Gas Flow Low Side	Welding Speed In/per minute
1	365	31/32	240"	30/CFH	16 ¹¹
2	365	31/32	240 ^{††}	30/CFH	14 ¹¹
3	365	30/31	240 ^{tt}	30/CFH	1311
4	365	31/32	240 [#]	30/CFH	9 1/2"
5	365	30/31	240 ¹¹	30/CFH	12"
6	365	31/32	240"	30/CFH	811

DETAILS OF STANDARD BUTT WELD FOR THE CARILLOY T-1 12 Steel Plate No. 50



Type of Welding Process - Aircomatic No. 21 Gun, Gas Shield

No. of Passes - 14

Electrode Type - A632, Alloy No. 2

Electrode Diameter - 1/16"

Gas Shield - Argon (No. 2) - 98% Argon (2% 0)

Gas Flow - Low Side 30/CFH

Current - Direct

Polarity - Reverse

Amperes - 160 to 365

Arc-volts - 30 ± 2 volts

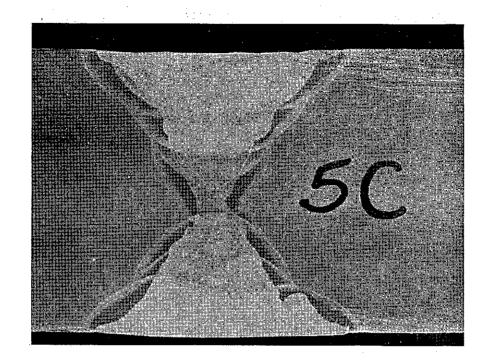
Average Welding Speed of Travel - 5", 10", 11", 14", 16" per min.

Starting Plate Temp. 70°F to 75°F

Finish Plate Temp. 400°F

Normal Cool Down to Room Temp.

Note: No. 1 weld pass was put in with 3/16" Airco 394 - low hydrogen electrode.



Cross-section of 1 1/2" butt joint semiautomatically welded using the Aircomatic inert gas shielded arc process with A632 electrode wire.

Welding pass detail for the welds are as follows:

Pass no.	Amps	Volts	wire feed per/min	gas flow low side	welding speed inches/per min
*1	160		•		5
2	365	31/32	240"	30/CFH	10.5"
3	365	31/32	24011	30/CFH	11"
4	365	31/32	240"	30/CFH]] ??
5	365	31/32	240#	30/CFH	7.5m
6	365	31/32	24011	30/CFH	14"
7	365	31/32	240**	30/CFH	14**
8 9	365	31/32	240"	30/CFH	16"
9	365	31/32	240"	30/CFH	16"
10	365	31/32	240"	30/cfh	16"
11	365	31/32	240 "	30/CFH	1611
12	365	31/32	240"	30/CFH	18"
13	365	31/32	240"	30/CFH	18"
$\overline{14}$	365	31/32	24011	30/CFH	18"

*The #1 weld pass was welded manually with low hydrogen 3/16 electrode-Airco #394 E-10016.

VIII APPENDIX SECTION D

SUMMARY OF TENSILE PROPERTIES

OF

TRANSVERSE BUTT WELDS

WITH

PHOTOGRAPHS

PLAN FOLLOWED IN CUTTING SPECIMENS From at CARILLOY T-1 STEEL TEST PLATES

1" 1. DISCARD 2" 2. REDUCED SECTION TENSILE SPECIMEN 1½" 3. CHARPY & MICRO SPECIMEN 3" 5. CHARPY 2" 2" 2" SPECIMEN 3" 5. CHARPY SPECIMEN 1½" 6. EXTRA TEST SPECIMEN 1½" 7. CHARPY & MICRO SPECIMEN 1½" 4. SPECIMEN SPECIMEN	ei – . Agi, i	From En CARILLOY T-	<u>,</u>	
2" 2. REDUCED SECTION TENSILE SPECIMEN 1½" 3. CHARPY & MICRO 2" 2" SPECIMEN 1½" 4. FREE BEND SPECIMEN 3" 5. CHARPY 2" 2" SPECIMEN 1½" 6. EXTRA TEST SPECIMEN 1½" 7. CHARPY & MICRO SPECIMEN 1½" 8. CHARPY & HARDNESS SPECIMEN 1½" 9. FREE BEND SPECIMEN 1½" 9. FREE BEND SPECIMEN 1½" 10. EXTRA TEST SPECIMEN SPECIMEN SPECIMEN SPECIMEN SPECIMEN SPECIMEN	i.	12" ———		12"
1½" 3. CHARPY & MICRO 2" 2" SPECIMEN 1½" 4. FREE BEND SPECIMEN 3" 5. CHARPY 2" 9. SPECIMEN 1½" 7. CHARPY & MICRO SPECIMEN 4" 8. CHARPY & HARDNESS SPECIMEN 1½" 9. FREE BEND SPECIMEN 1½" 9. FREE BEND SPECIMEN 1½" 10. EXTRA TEST SPECIMEN 2" 2" 2" 2" 2" 2" 2" 2" 2" 2" 2" 2" 2" 2	<u> </u>	1. DISCARD		DISCARD
1½" 4. FREE BEND SPECIMEN 3" 5. CHARPY 2" SPECIMENS 1½" 6. EXTRA TEST SPECIMEN 1½" 7. CHARPY & MICRO SPECIMEN 1½" 8. CHARPY & HARDNESS SPECIMENS 1½" 9. FREE BEND SPECIMEN 1½" 10. EXTRA TEST SPECIMEN SPECIMEN SPECIMEN SPECIMEN SPECIMEN SPECIMEN	↑ 2# ↓	2. REDUCED SECTION		TENSILE SPECIMEN
3" 5. CHARPY 2" Q 2" SPECIMENS 1½" 6. EXTRA TEST SPECIMEN 1½" 7. CHARPY & MICRO SPECIMEN 4" 8. CHARPY & HARDNESS SPECIMENS 1½" 9. FREE BEND SPECIMEN 1½" 10. EXTRA TEST SPECIMEN 2" SPECIMEN SPECIMEN SPECIMEN SPECIMEN SPECIMEN	1출 ^{tt}	3. CHARPY & MICRO	+ 2" + 2" 	SPECIMEN
1½" 6. EXTRA TEST SPECIMEN 1½" 7. CHARPY & MICRO SPECIMEN 4" 8. CHARPY & HARDNESS SPECIMENS 1½" 9. FREE BEND SPECIMEN 1½" 10. EXTRA TEST SPECIMEN	1½n	4. FREE BEND	_\	SPECIMEN
1½" 7. CHARPY & MICRO SPECIMEN 4" 8. CHARPY & HARDNESS SPECIMENS 1½" 9. FREE BEND SPECIMEN 1½" 10. EXTRA TEST SPECIMEN	3"	5. CHARPY	2" 0 2"	 specimens
8. CHARPY & HARDNESS SPECIMENS 1½" 9. FREE BEND SPECIMEN 1½" 10. EXTRA TEST SPECIMEN	기출#	6. EXTRA TEST		SPECIMEN
8. CHARPY & HARDNESS SPECIMENS 1½" 9. FREE BEND SPECIMEN 1½" 10. EXTRA TEST SPECIMEN	수 구출 ¹¹	7. CHARPY & MICRO		SPECIMEN
1 10. EXTRA TEST SPECIMEN	1.	8. CHARPY & HARDNESS	2" 2"	3 4
† 10. EXTRA TEST SPECIMEN	구불"	9. FREE BEND		SPECIMEN
\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\	†	10. EXTRA TEST	77 77 1 0 77	SPECIMEN
	\$# 	11. REDUCED SECTION	MEL.	TENSILE SPECIMEN

Extra Test Specimens for Proof Testing.

PLAN FOLLOWED IN CUTTING SPECIMENS

From 1" and 12" Carilloy T-1 Steel Test Plates

		From 1" and 12" Ca	ri]	lloy T-1 Steel Test Plates	
		911-	+	15"	
		DISCARD			1
4	12"	#1 FATIGUE		SPECIMEN	
١	2"	#1 REDUCED SECTION	WELD	TENSILE SPECIMEN	
•	1211	#1 FREE BEND		SPECIMEN	
7	18"	#2 FATIGUE		· SPECIMEN	
3		===#1 SIDE BEND====		SPECIMEN	
	2"	#2 REDUCED SECTION	MELD	TENSILE SPECIMEN	
,	i 기울 ⁿ	#2 FREE BEND		SPECIMEN	म् तंत्र
. 1	18"	#3 FATIGUE		SPECIMEN	1
3 -		#2 SIDE BEND	 	SPECIMEN	
	, , , ч ↓		&] 	HARDNESS	
•	<u>↓</u> 18"	#4 FATIGUE	‡ <i>-</i>	specimen	
	† 2″ †	CHARPY	MELD		
_	7 g n	#5 FATIGUE	 	SPECIMEN	
	1	DISCARD	;		<u> </u>

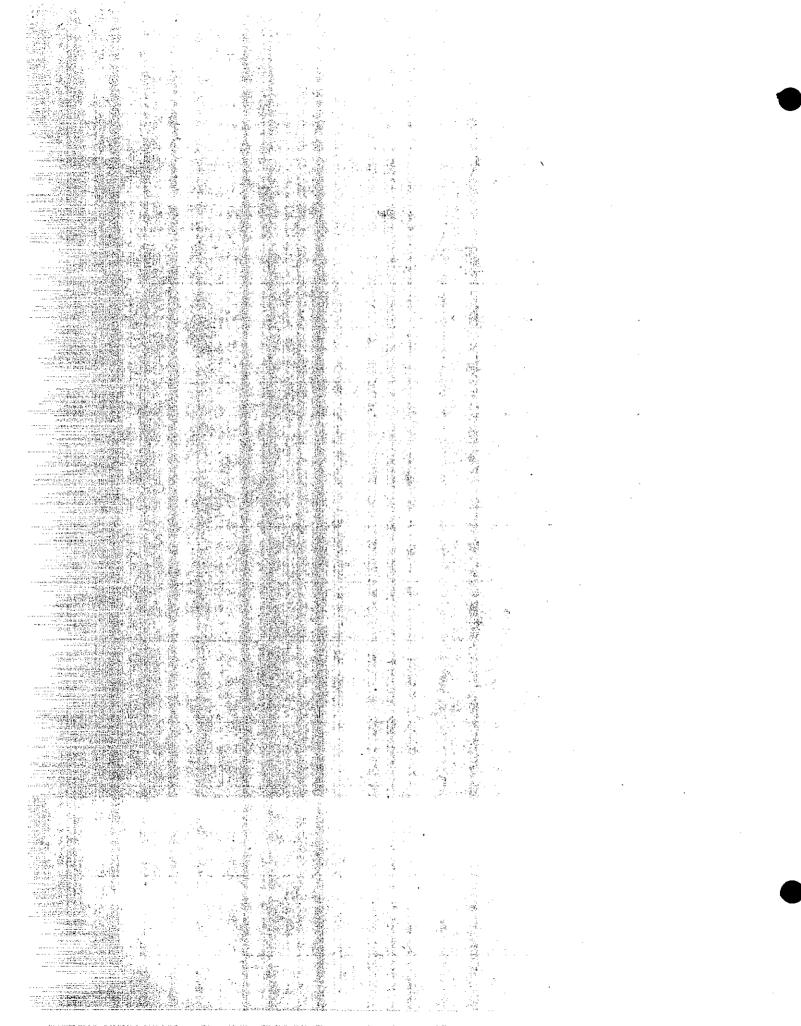
USS CARILLOY T-1 STEEL WELDED CONDITION TRANSVERSE BUTT WELDED --

MECHANICAL PROPERTIES

						,	F		1	
Spec.	Electrodes Used	Welding Process Used	Yield psi	U. T. S.	% Elong. in in.	Reduc. Area	% Fatigue Elong.Reduc.Endrance in in. Area Limit psi	Plate Thick- ness in in.	Location of Failure	Detail of standard Reduced-section tension specimens
2°A-1	E-11016 (Tentative)	A.O.Smith SW - 91 Manual	not recorde	not 116,000 recorded	791	28%		# Ti&	н. А. Z.	Direction of rolling
2-4-2	#	=	=	119,200	11.5%	9.2%	:	= ⊢[∞	H.A.Z.	4
2-B-1	r æ ∈	15 (109,000	120,500	12%	17%	37,900	(# (Jct. Weld Met.& HAZ	
2 B B C	# (004,111	122,900	19%	25%	37,900	i⊸ ≅ (Weld Met. & Jot. HAZ & P.N.	This section machined by milling
2.6.7	#	∰a* Ben	86,800	97,000	35%	%0†7	37,900	124	Weld Met. & Jct. HAZ	Weld metal machined flush with base metal
2-0-2	(# (C 🛎 🔾	004,08	90,700	35%	50%	37,900	11 TE	V Shape Jct. HAZ & PM	Edge of widest face of weld Note: All specimens were
3ª A ª 1	E-10016	Airco 353 Manual	93,000?	119,500	13%	20%	1	± ∞ =	H.A.Z.	cut by metal s for width
3-A-2	# (not recorde	not 122,000 recorded	13%	16%	ŧ	' ≠	H,A,Z,	HAZ & H.A.Z heat affected zone
3-B-1	:	, 4=	95,000	110,900	20%	33%	32,900	· == i	Weld Met.	s junction
3-B-2	·#	, and	107,200	123,300	20%	28%	32,900	; <u>=</u> 	Weld Met.	
3-C-1	(E	(=	83,700	95,300	37%	63%	32,900	# (1 00 	Parent Metal	rom. = parent metal.
3-0-2	(=	Œ	85,700	97,400	36%	%09	32,900	1 1 1 1 1 1 1	Brent Metal	65
1	•	τ			`	``	-	1		

USS CARILLOY T-1 STEEL WELDED CONDITION TRANSVERSE BUTT WELDED--MECHANICAL PROPERTIES

	4		k-1/1 .	→	\wedge			Δ)		Exh	ibit	66	·
Detail of Standard Reduced-section tension specimens	- Direction of Rolling		= 10		This section machined	by milling Weld metal machined	Edge of widest face of weld		cut by metal s for width	# N	II (0)	P.M. = parent metal W.M. = weld metal	
	Center of weld mtl.	Jct. of HAZ & P.M.	Weld Metal	=	ŧ	From Jct. HAZ & P.M. Into W.M.	H.A.Z.	H.A.Z.	Jct., HAZ & P.M., into small part W.M.	Jet. HAZ & P.M.intoW.M	Parent Metal	=	
Plate Thick- ness in in.	# ∏α	≈ ⊢[02	=	` ≅	127	는 문 문	= -1\a	# 02	; #= ;	: :-	13.1	112	
e Ice	Tad		40,700	1,0,700	40,700	10,700			39,800	39,800	39,800	39,800	
% Reduc Area	214%	35%	26%	21%	34%	11%	701	13%	27%	29%	43%	%0†	
% % Elong.Reduc in in. Area	18%	23%	18%	17%	18%	35%	12%	13%	23%	25%	2.3	27%	,
U. T. S. psi	115,000	92,800 113,200	99,300 115,000	103,800 116,000	78,900	102,500	126,500 led	122,000	102,300 125,200	104,000121,800	90,000 101,200	93,000 106,400	
Yield psi	93,000	92,800	99,300	103,800	67,900	90,000	not 120	Q==	102,300	10/1,000	90,000	93, 000	
Welding Process Used	Unionmelt. #80 Flux	= 1	#	. <u>w</u>	t	for t	Aircomatic. Argon #2 gas shieïd	=	. =	= :	gillion gende	E	1
Electrodes Used	311	= (die Te	-	· ##	. = .	A 632	<u> </u>	: #	· 🚆 .	data data	=	1
Spec.#		4-A-2	-B-	4-B-2	1-0-1	7-0-1	5-A-1	5-A-2	T E E	7. B S	5-6-1	5-0-5	



USS CARILLOY T-1 STEEL WELDED CONDITION TRANSVERSE BUTT WELDED

MECHANICAL PROPERTIES

								Exhibi.	t 67
	Detail of standard Reduced-section tension specimens	Direction of	14			Weld metal machined / flush with base metal	Edge of widest face of weld	Note: All specimens were cut by metal saw for width HAZ = heat affected zone Wtl.* metal P.M.* parent metal W.M.* weld metal Jot.* junction	
	Location of Failure	Weld Mtl thru HAZ to Parent Metal	Weld Mtl.	V Shape Jet.HAZ & P.M.	Jet. HAZ & P.M. small part W.M.	P.M.	P.M.		
: MKTLES	Plate thick- ness in in.	2 '	# (1) (X)	# (H	₽ '	114	112 123		
MECHANICAL FROFERTIES	Fatigue Endurance Limit	į	:	32,700	32,700	32,700	32,700	,	
МЕСНАМ	% Reduc Area	32%	33%	15%	16%	1,8%	16%		•
	Elong.	20%	23%	18%	17%	25%	26%		
	U. T. S. Psi	118,600	121,200	116,300	124,600	95,600	98,700		
	Yield psi	100,600	100,500	110,500	110,200	85,800	87,300	•	
	Welding Process Used	Airco 352 Manual	## (₹ (# 1	<u></u>	(# €		
	Welding Electrodes Process Used Used	E-12015	= 1	E (# 1	#	(#= (
	Spec.	6-A-1	6-A-2	6-B-1	6-B-2	L-2-9	6-6-2		

MANUAL WELDING

TENSILE FAILURE PHOTOGRAPHS

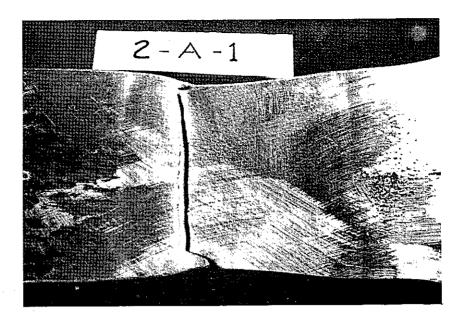
OF

TRANSVERSE BUTT WELDS

MADE WITH

A.O. SMITH

S.W. 91, LOW HYDROGEN ELECTRODES (E-11016 TENTATIVE)



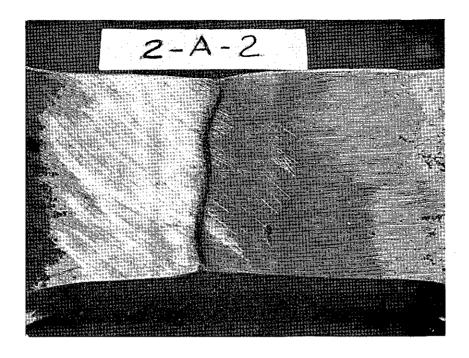
Face view

2" strap tensile test on 1/2" butt joint welded using the A. O. Smith process Yield not recorded Ultimate 116,000 psi 2" elongation 16% Red Area 28%

Failure in heat affected zone

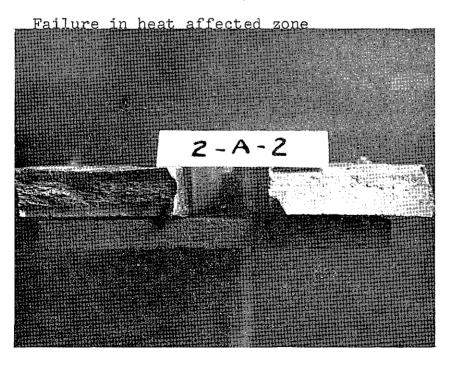


End view
Note rolling structure

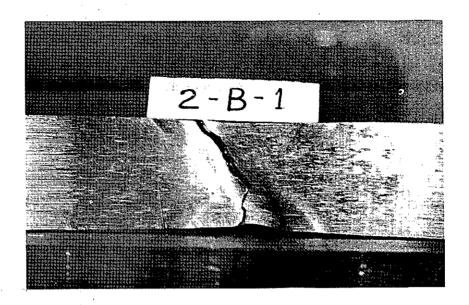


Face view

2" strap tensile test on 1/2" butt joint welded using the A. O. Smith process
Yield not recorded
Ultimate 119,200 psi
2" elongation 11.5 %
Red Area 9.0 %



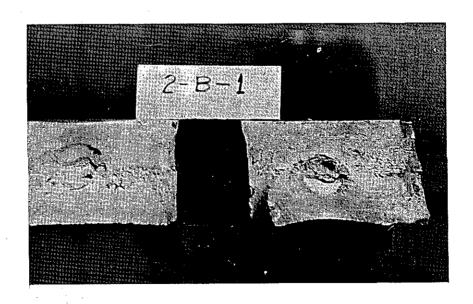
End view Note rolling structure



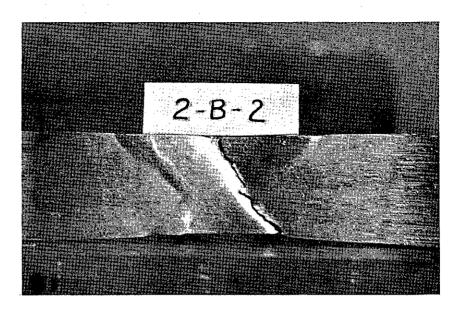
Side view

2" strap tensile test on 1" butt joint welded using the A. O. Smith process
Yield 109,000 psi
Ultimate 120,500 psi
2" Elongation 12%
Red Area 17%

Failure in heat affected zone and weld metal



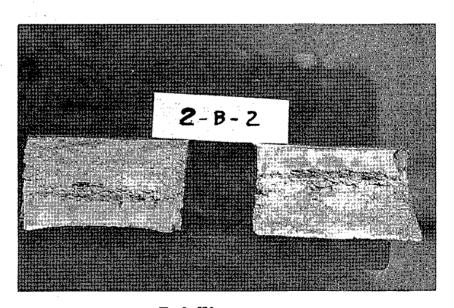
End view Note large slag inclusion



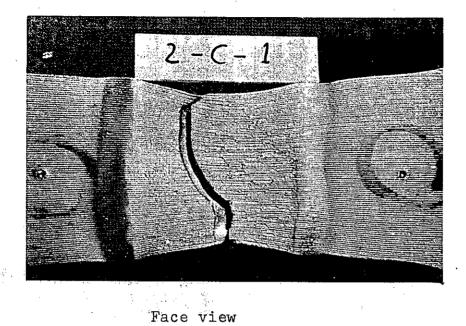
Side View

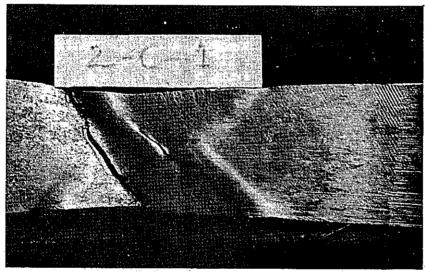
2" strap tensile test on 1" butt joint welded using the A. O. Smith process Yield 111,400 psi Ultimate 122,900 psi 2" Elongation 19% Red Area 25%

Failure in heat affected zone



End View

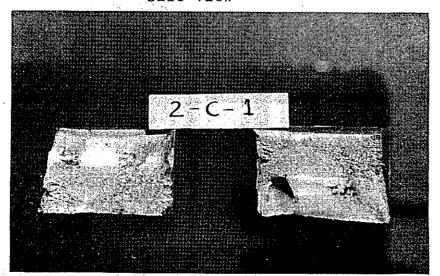




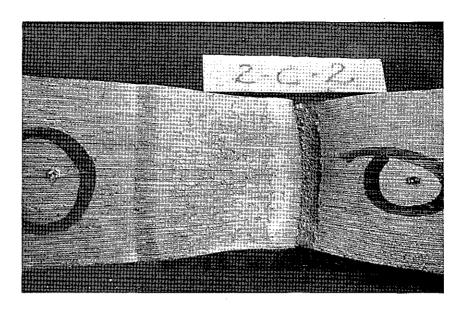
2" strap tensile test on 1 1/2
welded using 6...
Smith process.
Yield 86,800 psi
Ultimate 97,000 psi
Colongation 35 %
40 % on 1 1/2" butt joint welded using the A. O.

Failure in weld and heat affected zone

Side view



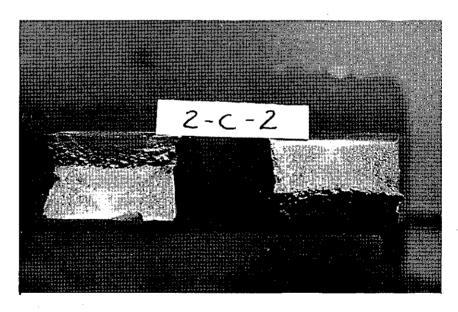
End view Note slag inclusion



Face view

2" strap tensile test on 1 1/2" butt joint using the A. O. Smith process
Yield 80,400 psi
Ultimate 90,700 psi
2" elongation 35 %
Red Area 50 %

Failure in heat affected zone



End view

MANUAL WELDING

TENSILE FAILURE PHOTOGRAPHS

OF

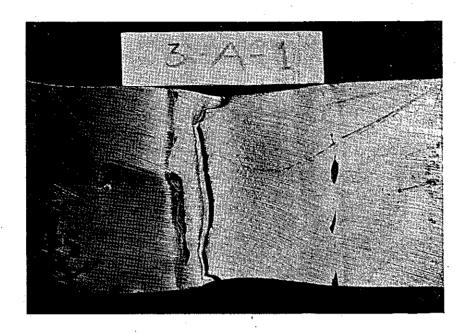
TRANSVERSE BUTT WELDS

MADE WITH

AIRCO

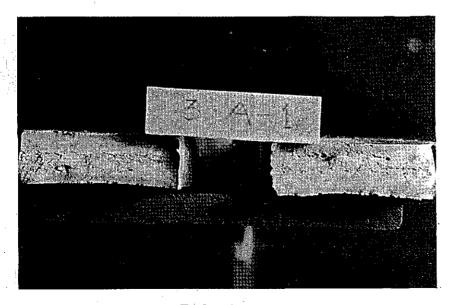
353, LOW HYDROGEN ELECTRODES

(E-10016)

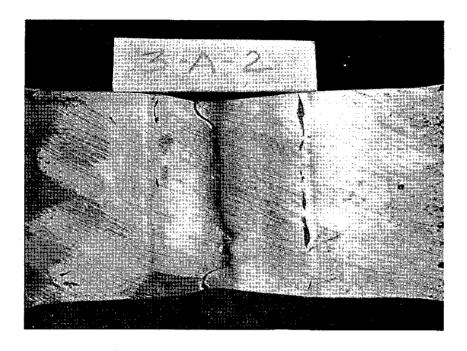


Face view

2" strap tensile test on 1/2" butt joint manually welded using Airco 353 electrodes Yield 93,000 psi Ultimate 119,500 psi 2" elongation 13% Red Area 20%

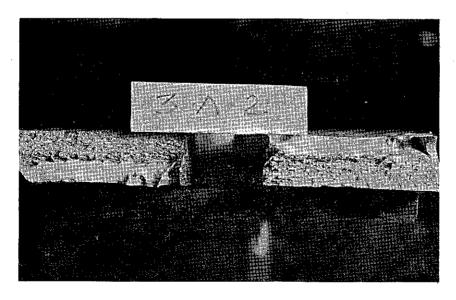


End view
Note numerous pinhole inclusions in weld metal



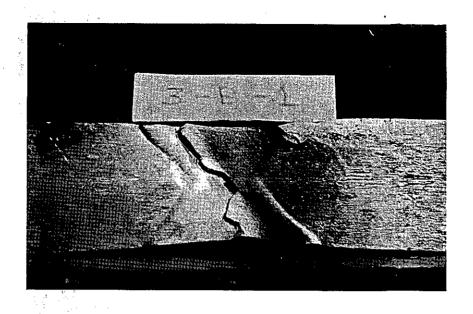
Face view

2" strap tensile test on 1/2" butt joint manually welded using Airco 353 electrodes Yield not recorded Ultimate 122,000 psi 2" elongation 13 % Red Area 16%



End view

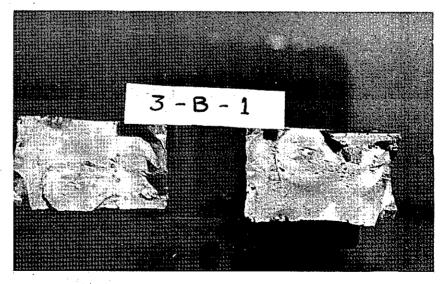
Note fish eye void and rolling structure



Side view

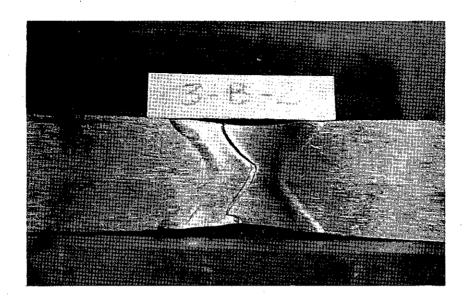
2" strap tensile of 1" butt joint manually welded using Airco 353 electrodes
Yield 95,000 psi
Ultimate 110,900 psi
2" Elongation 20%
Red Area 33%

Failure in Weld Metal



End view

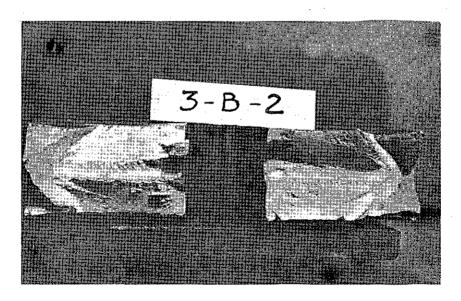
Note numerous inclusions in fracture section



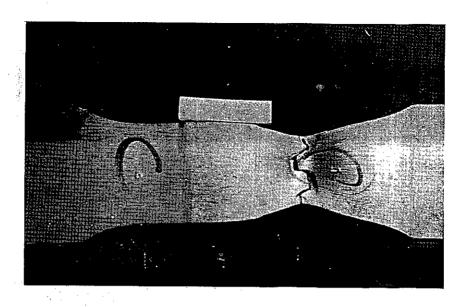
Face view

2" strap tensile test of 1" butt joint manually welded using Airco 353 electrodes Yield 107,200 psi Ultimate 123,300 psi 2" Elongation 20% Red Area 28%

Failure in weld metal



End view



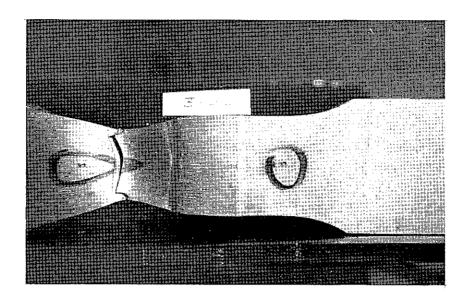
Side view

2" strap tensile of 1 1/2" butt joint manually welded using Airco 353 electrodes
Yield 83,700 psi
Ultimate 95,300 psi
2" elongation 37 %
Red Area 63 %

Failure in parent metal



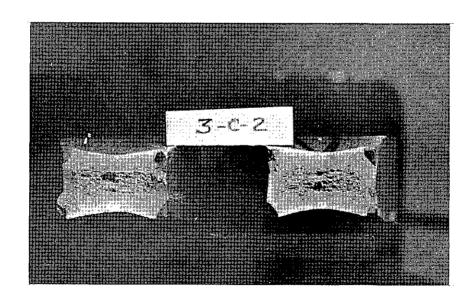
End view
Note parallel shear



Side view

2" strap tensile of 1 1/2" butt joint manually welded using Airco 353 electrodes.
Yield 85,700 psi
Ultimate 97,400 psi
2" elongation 36 %
Red Area 60 %

Failure in parent metal



End view

AUTOMATIC WELDING

TENSILE FAILURE PHOTOGRAPHS

OF

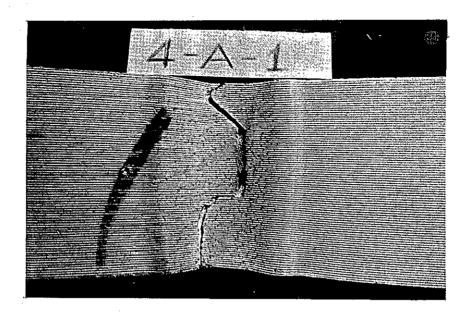
TRANSVERSE BUTT WELDS

MADE WITH

UNIONMELT SUBMERGED ARC PROCESS

WITH

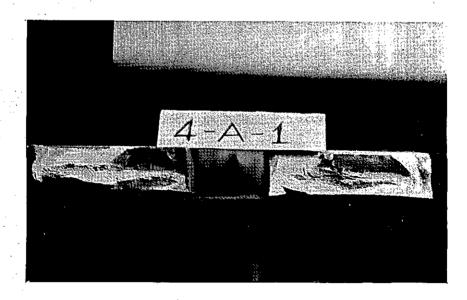
OXWELD 866 ELECTRODE WIRE AND 80 FLUX



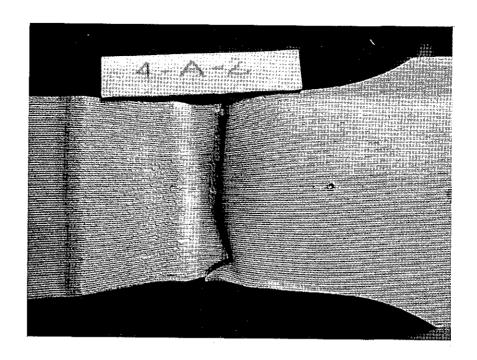
Face view

2" strap tensile test of 1/2" butt joint welded using the Unionmelt process Yield 93,000 psi Ultimate 115,000 psi 2" elongation 18 % Red Area 24 %

Fáilure in weld metal



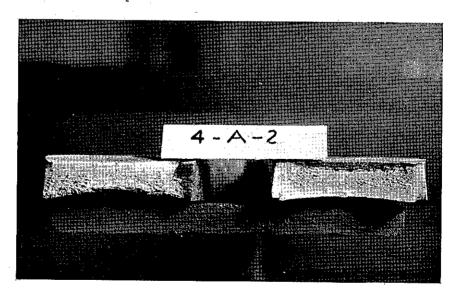
End view



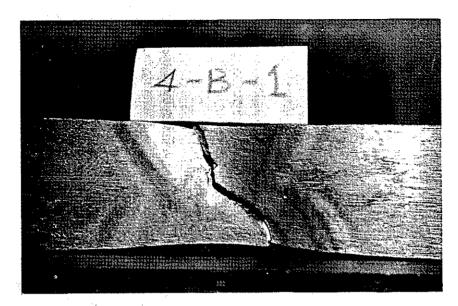
Face view

2" strap tensile test on 1/2" butt joint welded using the Unionmelt process Yield 92,800 psi Ultimate 113,200 psi 2" elongation 23 % Red Area 35 %

Failure in parent metal



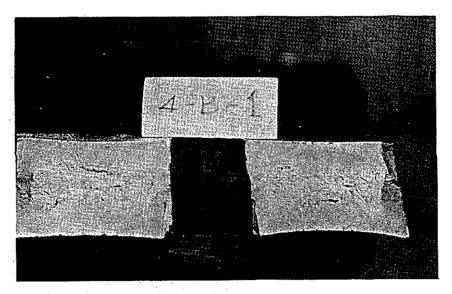
End view
Note rolling structure



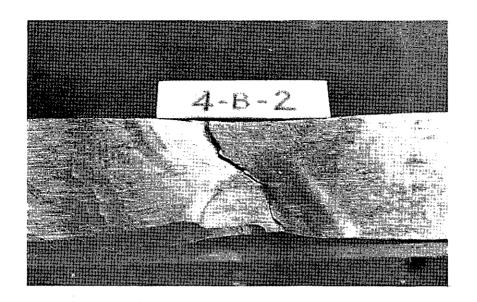
Side view

2" strap tensile test of 1" butt joint welded using the Unionmelt process Yield 99,300 psi Ultimate 115,000 psi 2" elongation 18 % Red Area 26 %

Failure in weld metal.



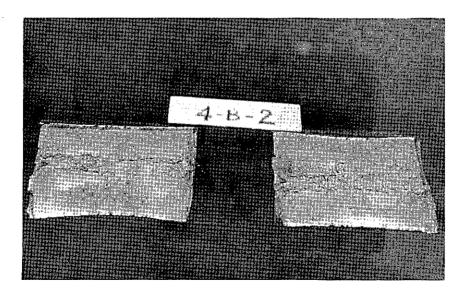
End view



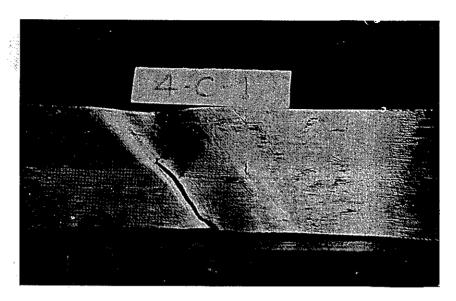
Side view

2" strap tensile on 1" butt joint welded using the Unionmelt process Yield 103,800 psi Ultimate 116,000 psi 2" elongation 17 % Red Area 21 %

Failure in weld metal



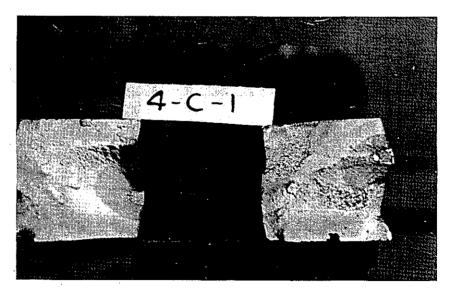
End view



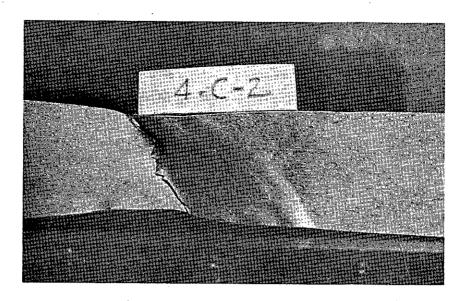
Side view

2" strap tensile test of 1 1/2" butt joint welded using the Unionmelt process
Yield 67,900 psi
Ultimate 78,900 psi
2" elongation 18 %
Red Area 34 %

Failure in weld metal



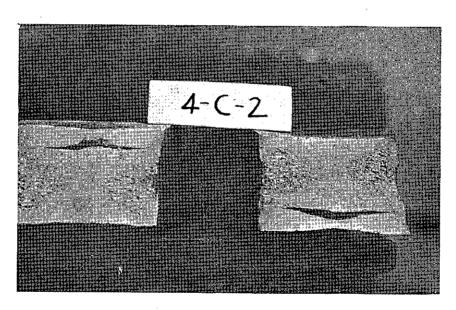
End view
Note extensive separation responsible for low strength of weld



Side view

2" strap tensile test of 1 1/2" butt joint welded using the Unionmelt process
Yield 90,000 psi
Ultimate 102,500 psi
2" elongation 35 %
Red Area 41 %

Failure in weld metal and heat affected zone



End view

SEMI-AUTOMATIC WELDING

TENSILE FAILURE PHOTOGRAPHS

OF

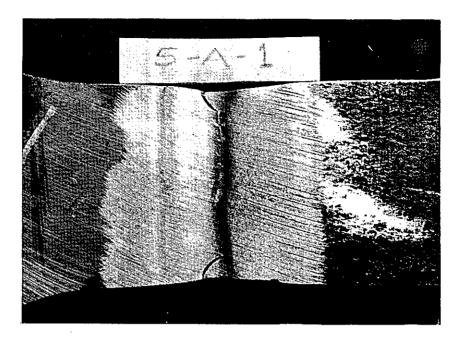
TRANSVERSE BUTT WELD

MADE WITH

AIRCOMATIC INERT GAS SHIELDED ARC PROCESS

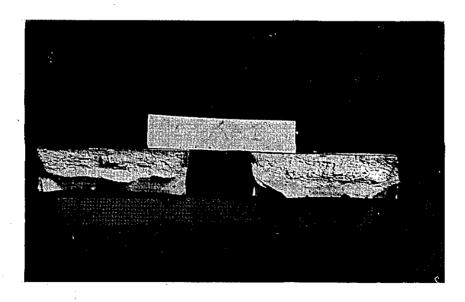
WITH

A632 ELECTRODE WIRE AND A 98%A - 2%02 SHIELD

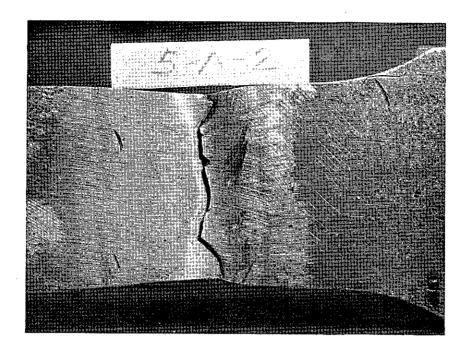


Face view

2" strap tensile test of butt joint welded using the Aircomatic process $(\frac{1}{2}$ " joint)
Yield not recorded
Ultimate 126,500 psi
2" elongation 12 %
Red Area 10 %

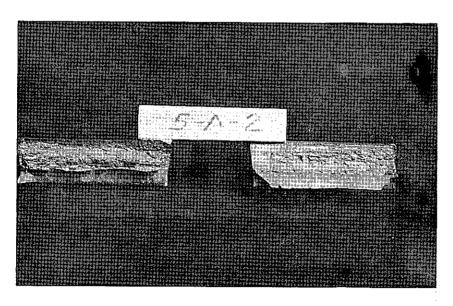


Side view

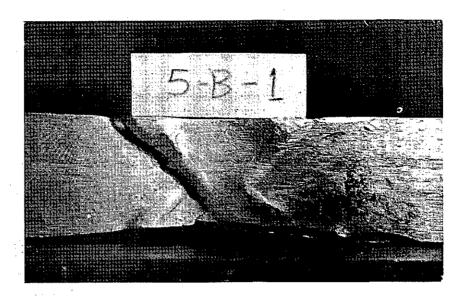


Face view

2" strap tensile test of 1/2" butt joint welded using the Aircomatic process
Yield not recorded
Ultimate 122,000 psi
2" elongation 13 %
Red Area 13 %



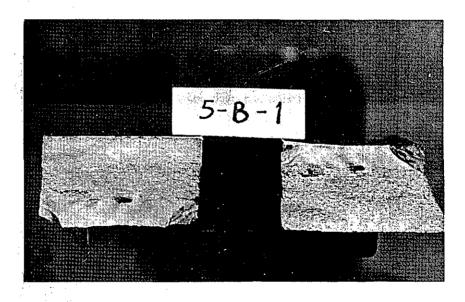
End view Note rolling structure



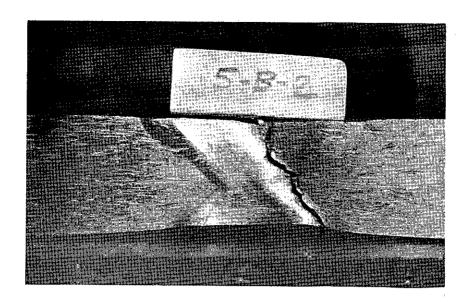
Side view

2" strap tensile test of 1" butt joint welded using the Aircomatic process

Yield 102,300 psi Ultimate 125,200 psi 2" elongation 23 % Red Area 27 %



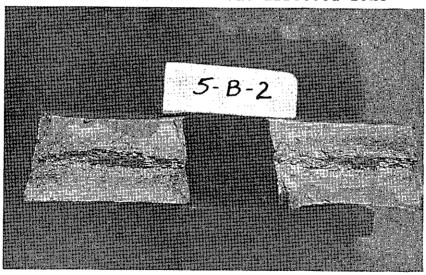
End view



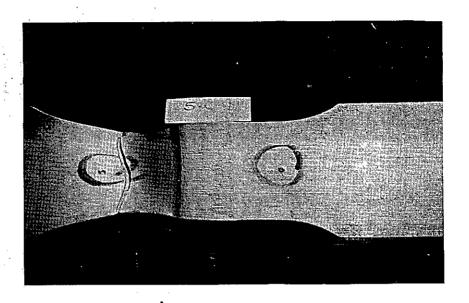
Side view

2" strap tensile test of 1" butt joint welded with the Aircomatic gas shielded arc process using A632 electrodes
Yield 104,000 psi
Ultimate 121,800 psi
2" elongation 25 %
Red Area 29 %

Failure initiated in heat affected zone



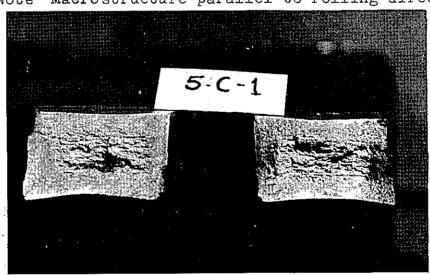
End view



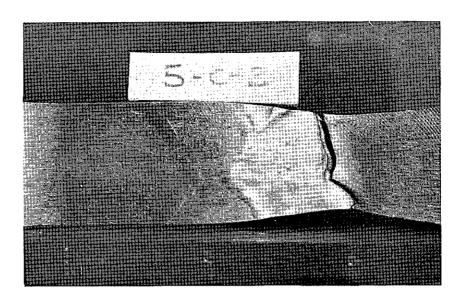
Face view

2" strap tensile test of 1 1/2" plate welded using the Aircomatic process
Yield 90,000 psi
Ultimate 101,200 psi
2" elongation 27 %
Red Area 43 %

Failure in parent metal Note Macrostructure parallel to rolling direction



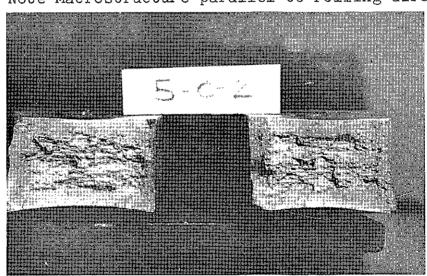
End view



Side view

2" strap tensile test of 1 1/2" butt joint welded using the Aincomatic process Yield 93,000 psi Ultimate 106,400 psi 2" elongation 27 % Red Area 40 %

Failure in parent metal Note Macrostructure parallel to rolling direction



End view

MANUAL WELDING

TENSILE FAILURE PHOTOGRAPHS

OF

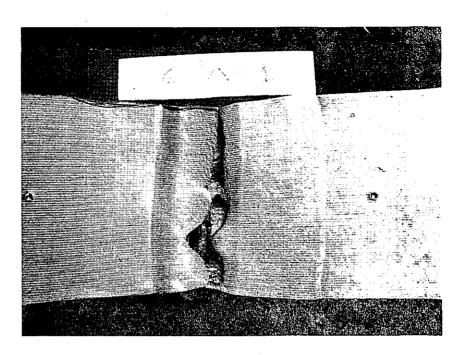
TRANSVERSE BUTT WELDS

MADE WITH

AIRCO

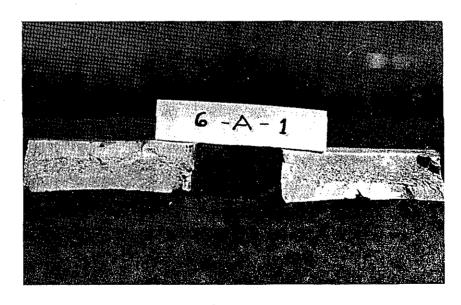
352, LOW HYDROGEN ELECTRODES

(E-10016)

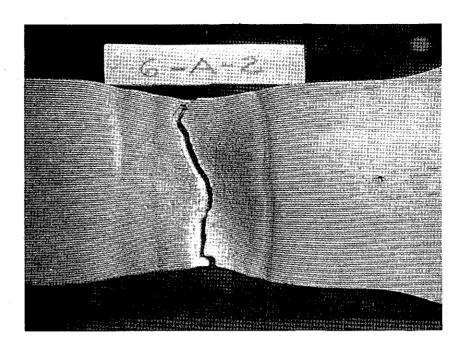


Face view

2" strap tensile test of 1/2" butt joint manually welded using Airco 352 electrodes Yield 100,600 psi Ultimate 118,600 psi 2" elongation 20 % Red Area 32 %



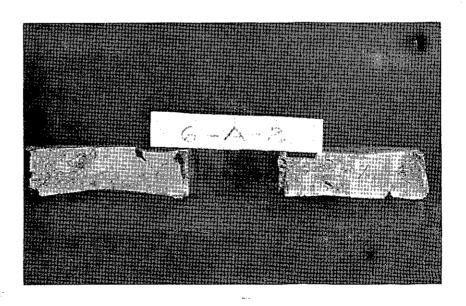
End view Note porous area similar to fisheye



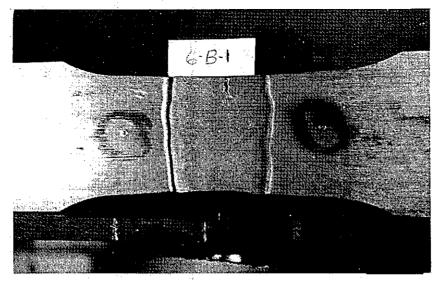
Face view

2" tensile test on 1/2" butt joint manually welded using Airco 352 electrodes
Yield 100,500 psi
Ultimate 121,200 psi
2" elongation 23 %
Red Area 33 %

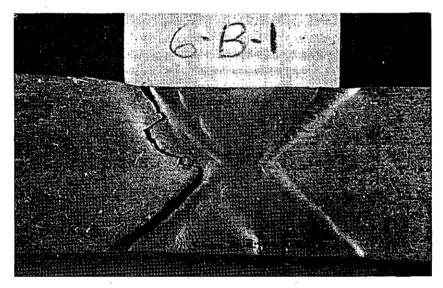
Failure in weld metal



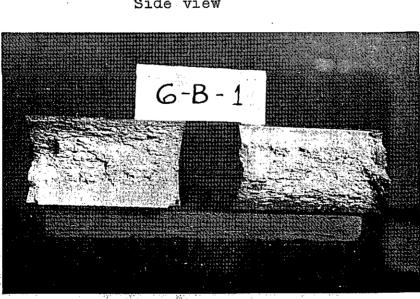
End view Note void left by gas bubble



Face view



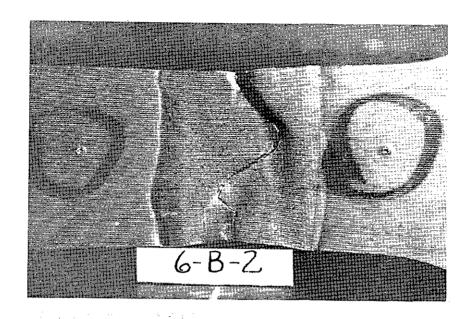
Side view



End view

2" strap tensile test of 1" butt joint welded using Airco 352 electrodes Yield 110,500 psi Ultimate 116,300 psi 2" elongation 18 % Red Area 15%

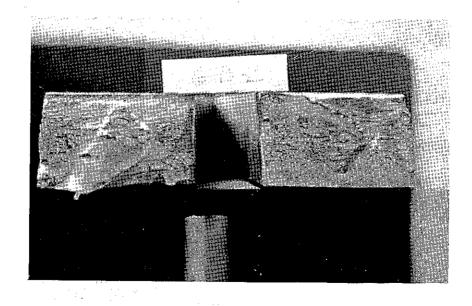
Failure in weld metal and heat affected zone



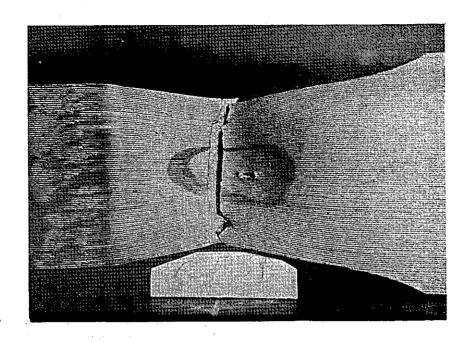
Face view

2" strap tensile test on 1" butt joint welded using Airco 352 electrodes
Yield 110,200 psi
Ultimate 124,600 psi
2" elongation 17 %
Red Area 16%

Failure in weld metal



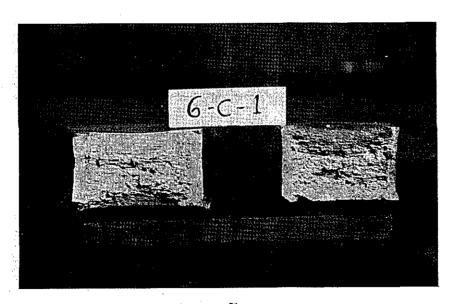
End view Note fisheye voids and numerous extensive inclusions



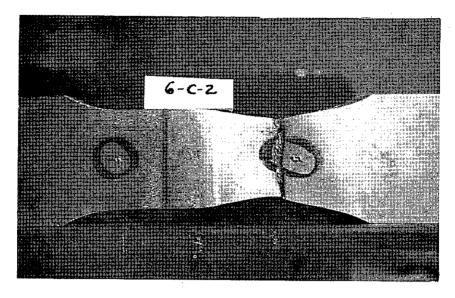
Face view

2" strap tensile test on 1 1/2" butt joint manually welded using the Airco 352 electrodes Yield 85,800 psi Ultimate 95,600 psi 2" elongation 25 % Red Area 48 %

Failure in parent metal



End view

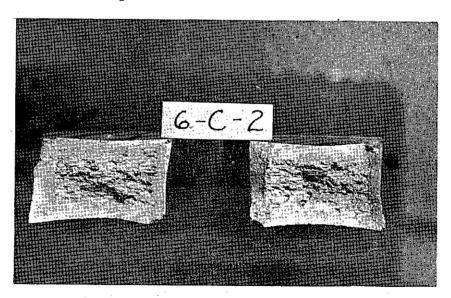


Face view

2" strap tensile test of 1 1/2" butt joint welded using the manual Airco 352 low hydrogen electrodes

Yield 87,300 psi Ultimate 98,700 psi 2" elongation 26 % Red Area 46 %

Failure in parent metal



End view

VIII APPENDIX SECTION E

SUMMARY OF BEND TESTS

OF

TRANSVERSE BUTT WELDS

WITH

PHOTOGRAPHS

PLAN FOLLOWED IN CUTTING SPECIMENS
From 10 CARILLOY T-1 STEEL TEST PLATES

,	12"	12"
I.11	1DISCARD	DISCARD
2"	2. REDUCED SECTION	TENSILE SPECIMEN
구글 ^미	3. CHARPY & MICRO	SPECIMEN SPECIMEN
121	4. FREE BEND	SPECIMEN//
3"	5. CHARPY	SPECIMENS III SPECIMENS
1章**	6. EXTRA TEST	SPECIMEN
구글!!	7. CHARPY & MICRO	SPECIMEN
4"	8. CHARPY & HARDNESS	SPECIMENS SPECIMENS
‡ 그늘'	9. FREE BEND	SPECIMEN //
* 그룹		SPECIMEN.
\$n	11. REDUCED SECTION	TENSILE SPECIMEN
+	12. DISCARD	DISCARD

[#] Extra Test Specimens for Proof Testing.

PLAN FOLLOWED IN CUTTING SPECIMENS

	From 1" and $1\frac{1}{2}$ " Carilloy T-1 Steel Test Plates							
	911	+	15"					
	DISCARD							
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	#1 FATIGUE		SPECIMEN					
† _2" ↓	#1 REDUCED SECTION	WELD	TENSILE SPECIMEN					
↓ ^{그쿨n}	#1 FREE BEND		SPECIMEN					
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211	#2 REDUCED SECTION	WELD	TENSILE SPECIMEN					
l ¹ zn	#2 FREE BEND		SPECIMEN					
118 to	#3 FATIGUE		SPECIMEN					
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<u>↓18</u> 11	#4 FATIGUE		SPECIMEN					
† 2" ↓	CHARPY	OF THE PERSON NAMED IN COLUMN 1						
78 11	#5 FATIGUE		SPECIMEN					
1/	DISCARD							

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TRANSVERSE BUTT WELDED - FREE BEND TEST SPECIMENS

Typical Detail of weld joint	ا این ا	$\begin{cases} \text{plate thickness} \\ \text{of } \frac{1}{2} \end{cases}$	machine flush	chînî	Ghip 600 machine flush	root /	plate thickness	S Root opening	600 machine flush	:	Chip 60 60 flush)			machine flush 600	
Heat #	ę.																
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Location of Fracture	Weld Metal	Weld Metal	H.A.ZP.M.	H, A.ZP.M.	H.A.ZP.M.	H.A.ZP.M.		H.A.ZP.M.	H.A.ZP.M.	Weld Metal	H.A.ZP.M.	H, A, Z, -P, M,	H.A.ZP.M.				
Elong.	38.5%	43.7%	25.6%	26.9%	45,3%	78.6%		29.7%	37.9%	44.1%	44.0%	32.8%	44.0%	•			
Welding Process	E-11016) A.O.Smith (Tentative) SW91 Manual	=	(**	: 500	·=	· #		Airco 353 Manual	=	1=	· #=	۰#	£				T
Electrode Used	(E-11016) (Tentative)	#	i den	(2	(5	į l i	1	Е-10016	ź	1 2	; 4	· =	: ==	1			
Spec.	2-4-1	2-A-2	2-B-1	2-B-2	2-0-1	2-0-2		3-A-1	3-A-2	3-B-1	3-B-2	3-6-1	3-0-2				

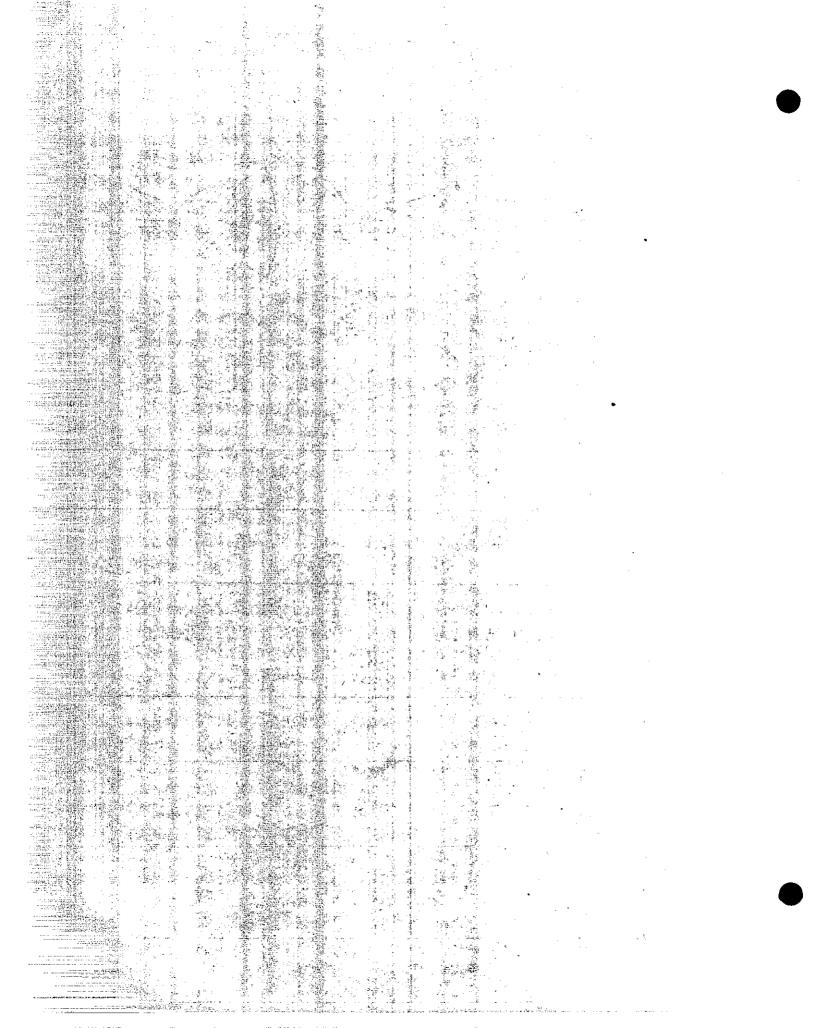


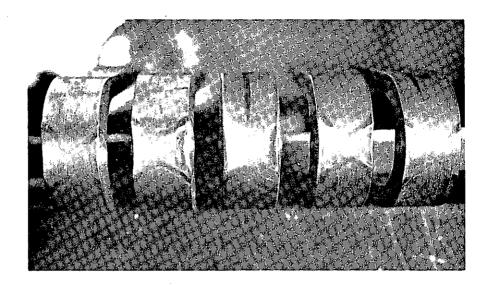
Exhibit 10'

machine flush machine flush s-machine flush plate thickness/ plate thickness Machine flush thickness - Root Opening 는 기원 οľ joint -Direction of Machining οţ Plate of 1814 N 009 1 Detail of weld Typical .609. 60°--009-. 8 Root opening opening machine flush 1 Root machine rlush Chip root Chip root Chip root Heat # Thick-1 2 1 2 .≡ .≡\∞ Plate ness # <u>|</u> Ţ. **≃** ⊢|Ω **≅** ⊢|않 = 02 **=** ⊠⊠ of. No Fracture No Fracture No Fracture H.A.Z.-P.M. H.A.Z.-P.M. H.A.Z.-P.M. H.A.Z.-P.M. W.M.-H.A.Z. Weld Metal Weld Metal Weld Metal Weld Metal Fracture Location Elong. 25.0% 43.8% 45.3% 59,5% 28.8% 38.9% Unionmelt 41.3% #80 Flux 148.0% 39.3% 49.3% 38,2% 25.6% gas shield Aircomatic Welding Process Argon Electrode 0xweld 866-1/8" Used A632 = = 1= = : # Spec.# 4-B-2 5-A-2 5-B-2 5-0-5 4-A-2 4-0-1 4-0-5 5-0-1 4-A-1 4-B-1 5-A-1 5-B-1

TRANSVERSE BUTT WELDED - FREE BEND TEST SPECIMENS

TRANSVERSE BUTT WELDED - FREE BEND TEST SPECIMENS

p	
Typical Detail of weld joint	Chip root plate, thickness machine flush bot opening though to be flush bot opening blate thickness of 1" blat
Heat #	
Plate Thick- ness	다
Location of Fracture	H, A, Z, -P, M,
Elong.	25.0% 15.0% 16.14% 16.14%
Welding Process	Aireo 352 Manual " " " "
Electrode Used	H-12015
Spec.	6-A-1 6-B-1 6-G-1 6-G-1



3 2 5

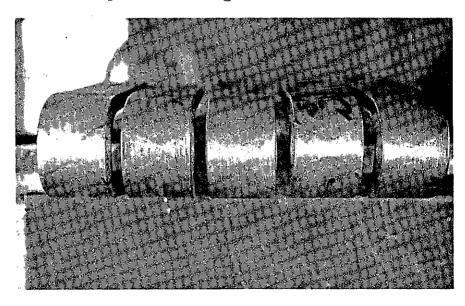
Guided side bend tests of 1" and 1 1/2" Butt joints welded as follows:

A.C.Smith process using SW91 electrodes Airco process using 353 electrodes

Unionmelt process using #80 flux and Oxweld 866 electrode wire

5 Aircomatic process using #2 gas shield and A632 electrode wire

Airco process using 352 electrodes



6 5 3 2

MANUAL WELDING

PHOTOGRAPHS

OF

FREE FACE BEND TESTS

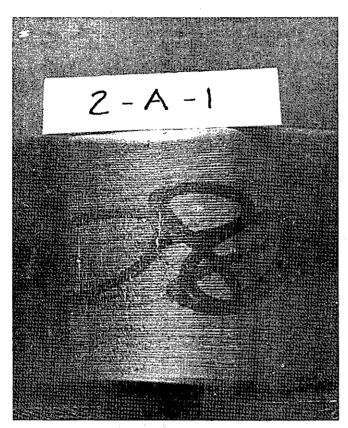
ON

BUTT WELDED JOINTS

USING

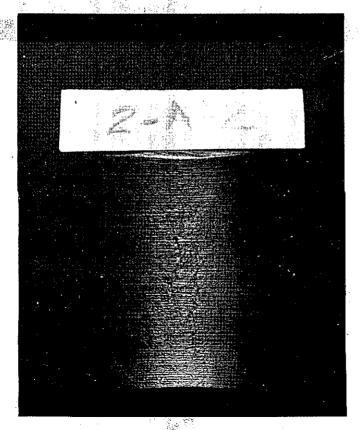
A.O.SMITH

S. W. 91, LOW HYDROGEN ELECTRODES (E-11016 TENTATIVE)



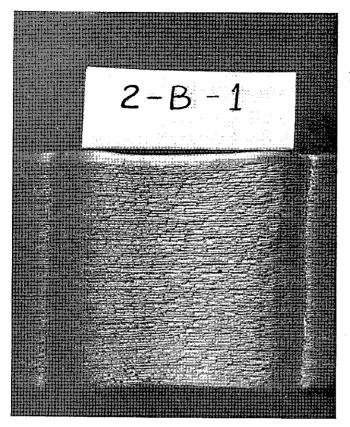
Failure in weld metal face

Elongation 38.5%

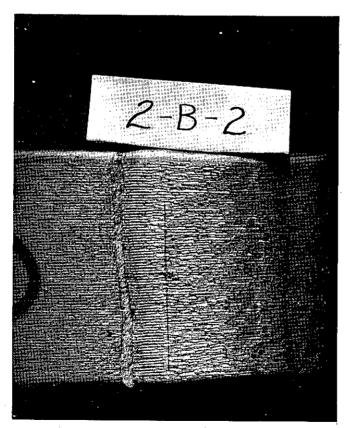


Failure in weld metal face

Elongation 43.7%

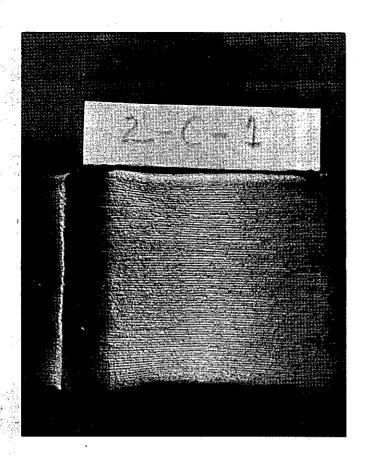


Failure in heat affected zone Elongation 25.6%



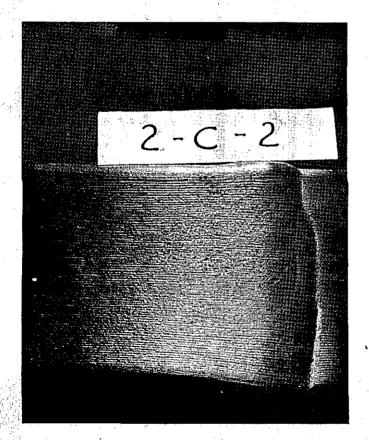
Failure in heat affected zone

Elongation 26.9%



Failure in heat affected zone

Elongation 45.3%



Failure in heat affected zone

Elongation 78.6%

MANUAL WELDING

PHOTOGRAPHS

OF

FREE FACE BEND TESTS

ON

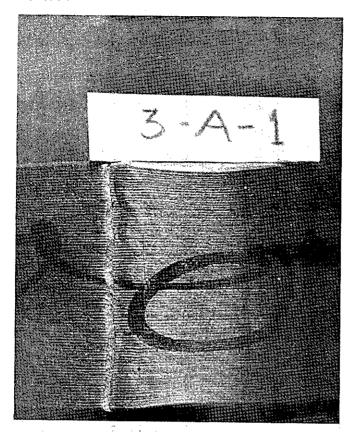
BUTT WELDED JOINTS

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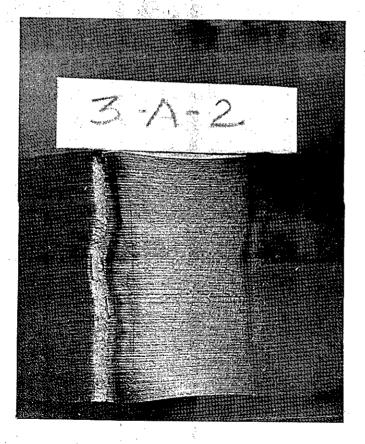
353, LOW HYDROGEN ELECTRODES

(E-10016)



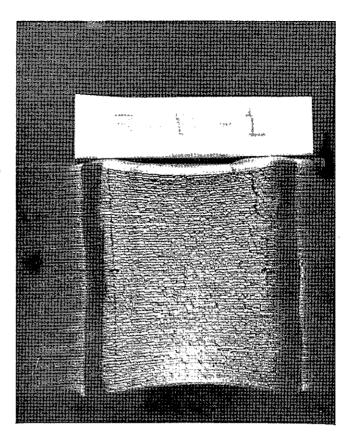
Failure in heat affected zone

Elongation 29.7%



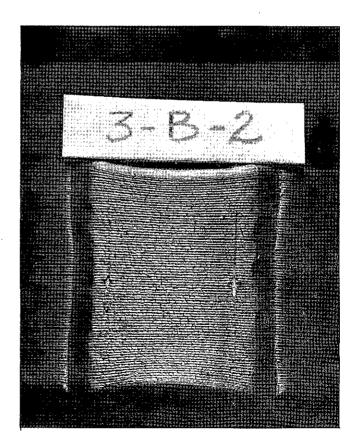
Failure in heat affected zone Elongation 37.9%

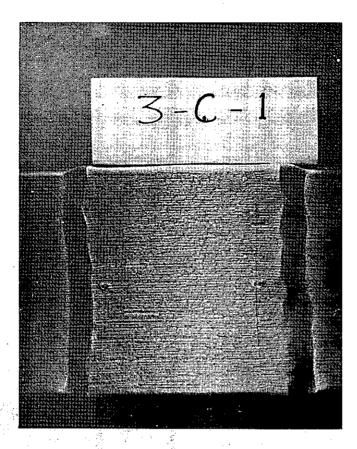
Failure in weld metal face
Elongation 44.1%



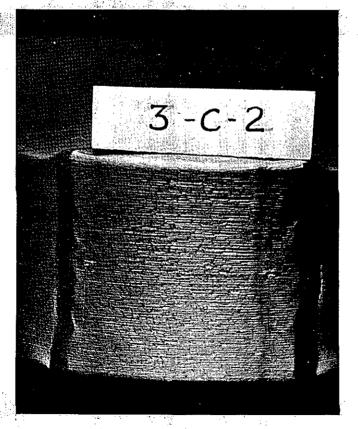
Failure in weld metal face and heat affected zone

Elongation 44.0%





Failure in heat affected zone Elongation 32.8%



Fäilure in heat affected zone Elongation 44.0%

AUTOMATIC WELDING

PHOTOGRAPHS

OF

FREE FACE BEND TESTS

ON

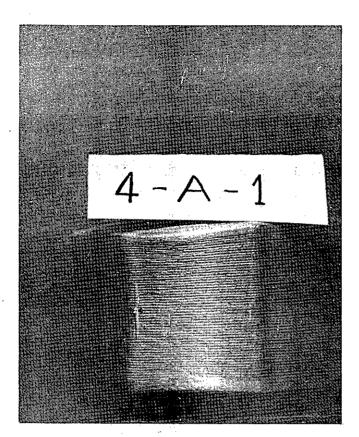
BUTT WELDED JOINTS

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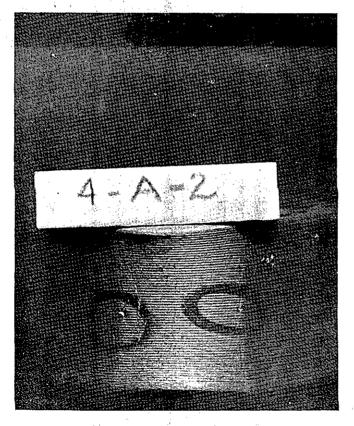
UNIONMELT SUBMERGED ARC PROCESS

· WITH

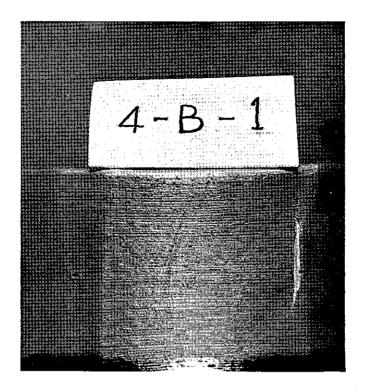
OXWELD 866 ELECTRODE WIRE AND 80 FLUX



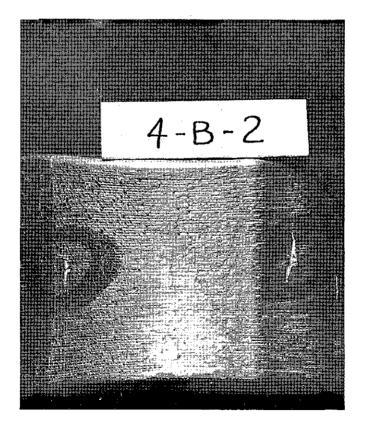
Failure in weld metal face
Elongation 41.3%



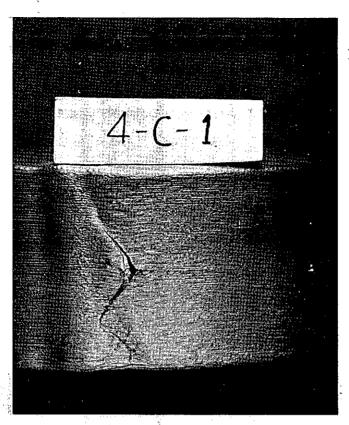
Failure in weld metal face Elongation 48%



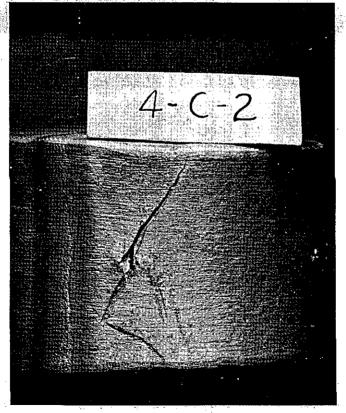
Failure in weld metal face Elongation 39.3%



Failure in weld metal face
Elongation 43.8%



Failure in weld metal face
Elongation 49.3%



Failure in weld metal face Elongation 45.3%

SEMI-AUTOMATIC WELDING

PHOTOGRAPHS

 \mathbf{OF}

FACE FREE BEND TESTS

OF

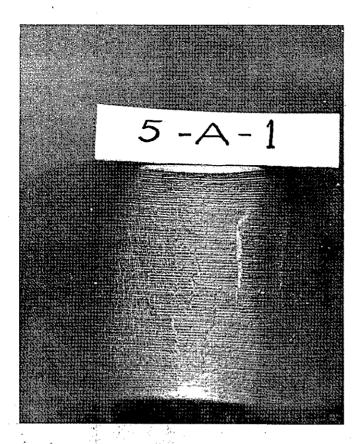
BUTT WELDED JOINTS

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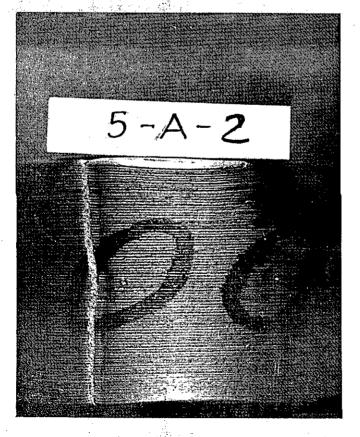
AIRCOMATIC INERT GAS SHIELDED ARC PROCESS

WITH

A632 ELECTRODE WIRE AND A 98%A - 2%02 SHIELD

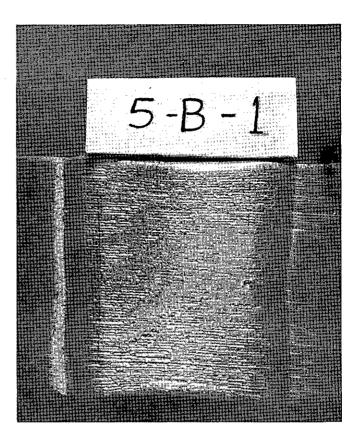


Failure in weld metal face Elongation 59.5%

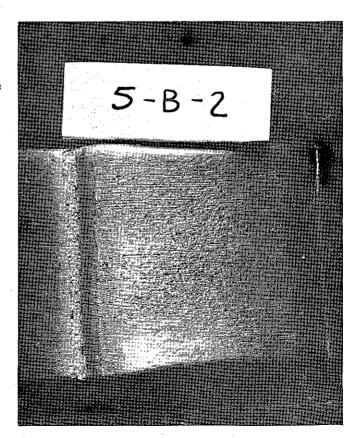


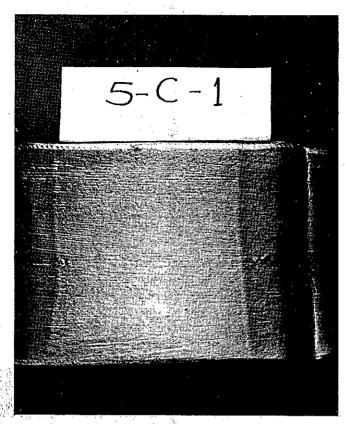
Failure in heat affected zone Elongation 25%

Failure in heat affected zone Elongation 28.8%

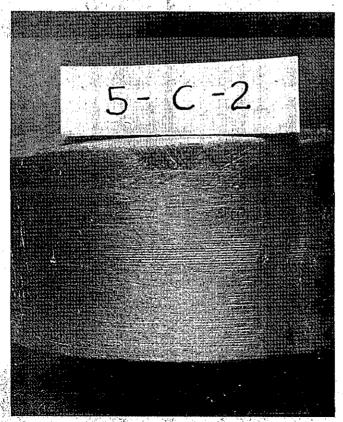


Failure in heat affected zone Elongation 38.2%





Failure in heat affected zone Elongation 25.6%



Failure in parent metal Elongation 38.9%

MANUAL WELDING

PHOTOGRAPHS

OF

FACE FREE BEND TESTS

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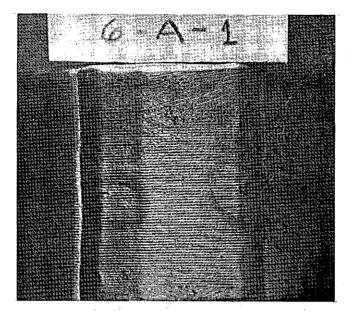
BUTT WELDED JOINTS

USING

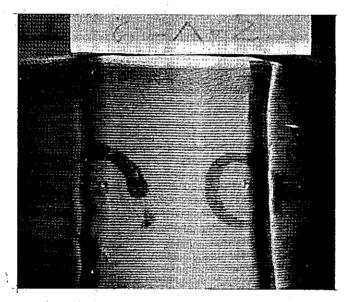
AIRCO

352, LOW HYDROGEN ELECTRODES

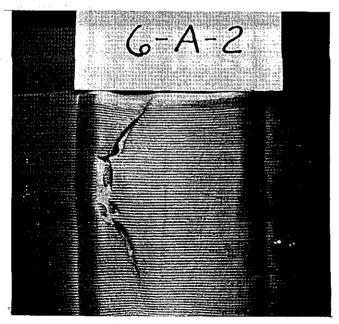
(E-12015)



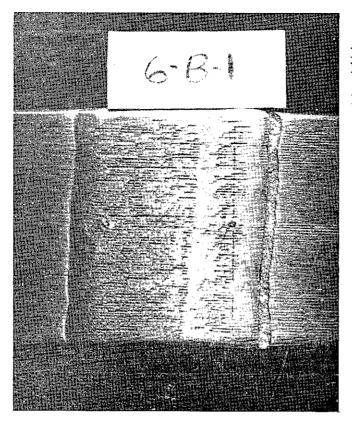
Failure in heat affected zone Elongation 25%



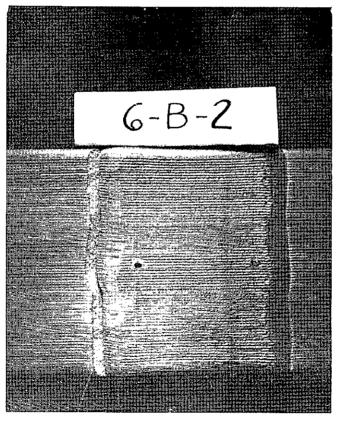
Failure in heat affected zone Elongation 23.9%



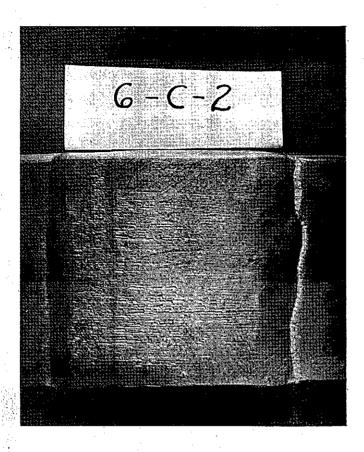
Failure in Weld metal face 60° bend



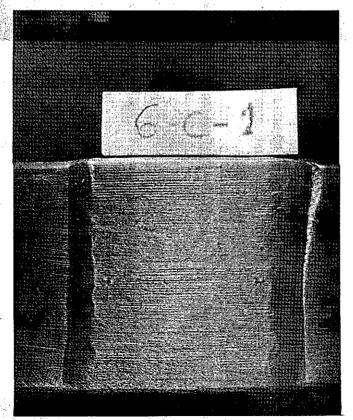
Failure in heat affected zone Elongation 15.3%



Failure in heat affected zone 13.3% Elongation



Failure in heat affected zone Elongation 16.4%

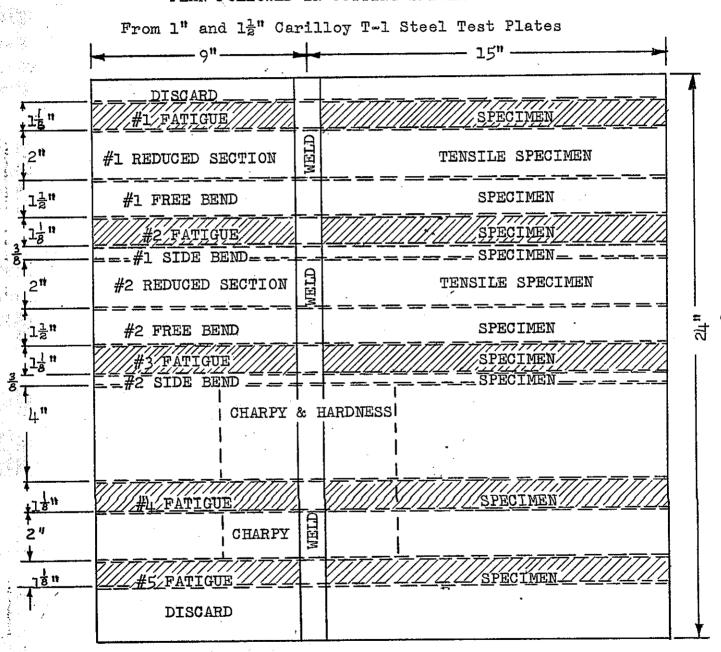


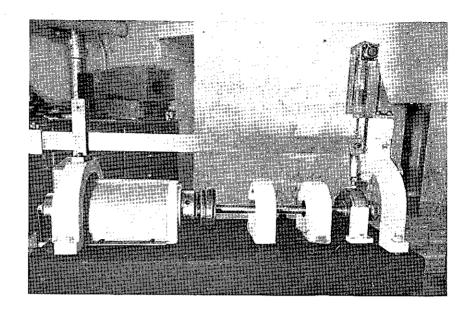
Failure in heat affected zone
Elongation 16.7%

VIII APPENDIX SECTION F

FATIGUE DATA
WITH
SN DIAGRAMS AND PHOTOGRAPHS

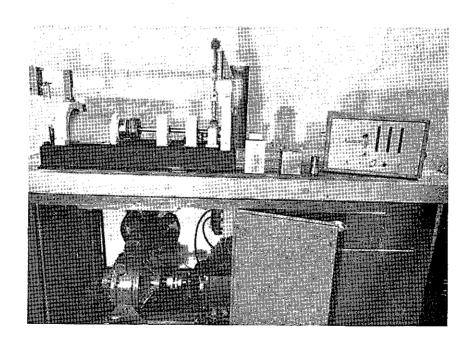
PLAN FOLLOWED IN CUTTING SPECIMENS

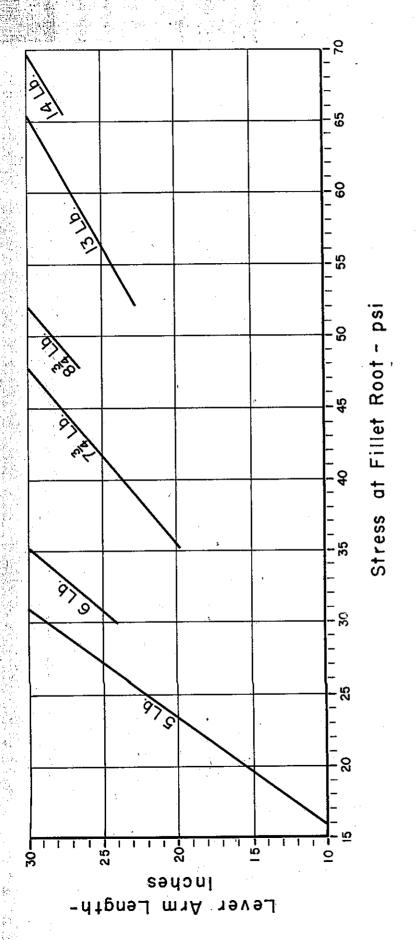




Fatigue machine with specimen in place showing driving motor, gearbox, table, electronic gear, and extra weights and collet.

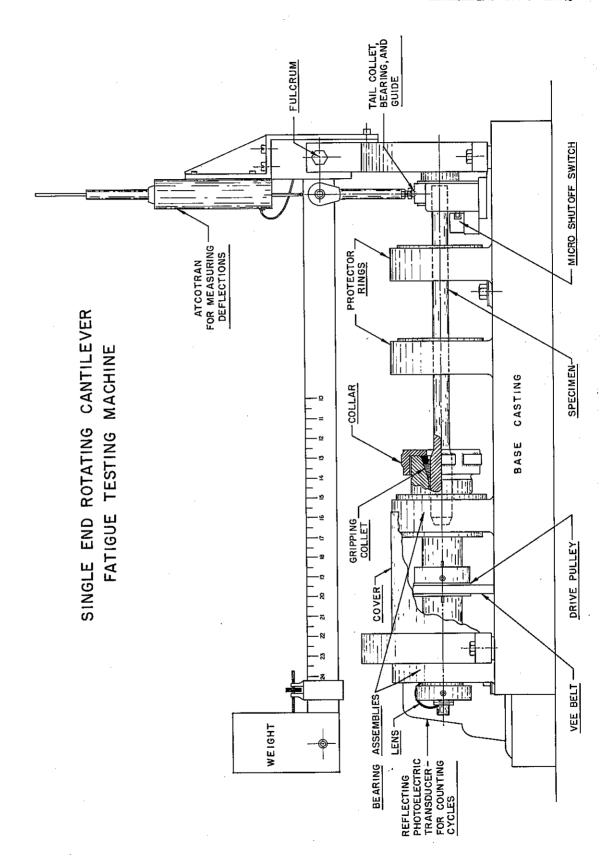
See following page for parts and details.

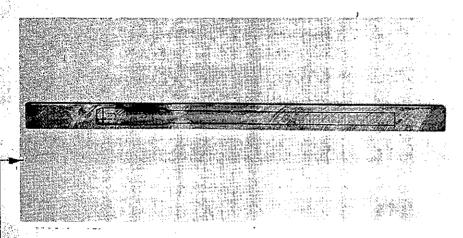




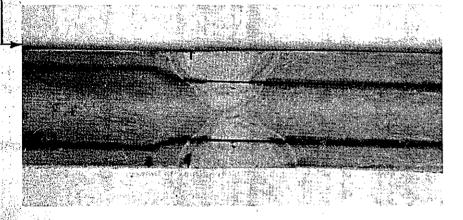
I"Radius 31"±.001 64 ±.001

WEIGHT POSITION CHART

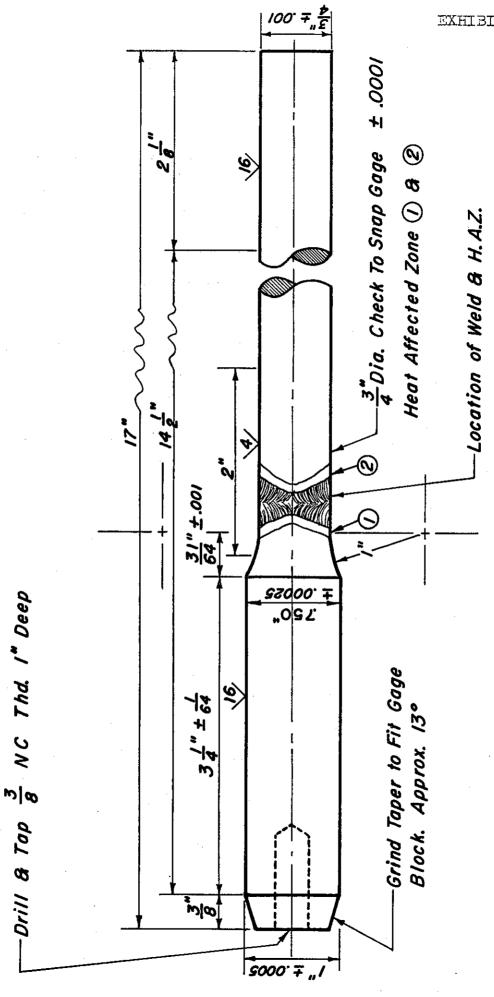




Macro sections through welded plates illustrating the position of the weld in the fatigue specimens.



Finished fatigue specimen. This one has been subjected to 10' stress cycles without failure. During a later retest it was stressed above its endurance limit and failed.



FATIGUE SPECIMEN

FATIGUE DATA AND SN DIAGRAMS

Points on the horizontal portions of the SN diagrams were not considered in calculating the solutions to the data. Points were eliminated where deviation from the SN curve exceeded the probable error by an amount greater than that specified under Chauvenet's criterion for discarding experimental values or where the inclusion of a single point made interpretation of the data impracticable.

The ordinates of the horizontal portions of the SN diagrams corresponding to the endurance limits were estimated from the data by visual inspection. These estimates were based on the ordinates of the "runout" points derived from specimens tested without failure, the ordinates of the lowest points derived from failed specimens (specimens with the lowest fatigue strength), the fit of these points into the limits of the probable error as extrapolated from the sloping to the horizontal portion of the SN diagram, and the abcissa of the break or knee in the diagram.

The fatigue specimens which failed through the gripped section were considered to have run without failure. These results are recorded on the SN diagrams as runout points (indicated on the diagrams as points with arrow attached) with abcissae smaller than 10⁷ cycles.

17. 17. 18. 18. 18. 18. 18. 18. 18. 18. 18. 18	-1"T-1 58,600psi	AircomathcA632, Argon 2, 39,800psi Union Mett 866, Mett 80, 40,700psi 40.5mith, 5.W-9, 37,900psi	Airco 352, E 12015, 32700 psi Airco 353, E10016, 32, 900 psi 74.7, 30, 800 psi	: []	STATE OF CALIFORNIA DIVISION OF HIGHWAYS MATERIALS & RESEARCH DEPARTMENT	S-N DIAGRAM Carilloy "T _i " Steel in Welded Condition	Fatigue Endurance in Single End Rotating Cantilever Testing Machine	6000 Cycles per. min. Date	,
						14½ 1/2 1/2 1/2 1/2 1/2 1/2 1/2 1/2 1/2 1/2	TEST SPECIMEN	4 5 6 7 8 9 105 2 3 4 5 6 7	Cycles

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MANUAL WELDING

FATIGUE FAILURE PHOTOGRAPHS

AND

SN DIAGRAMS

OF

TRANSVERSE BUTT WELDS

MADE WITH

A.O.SMITH

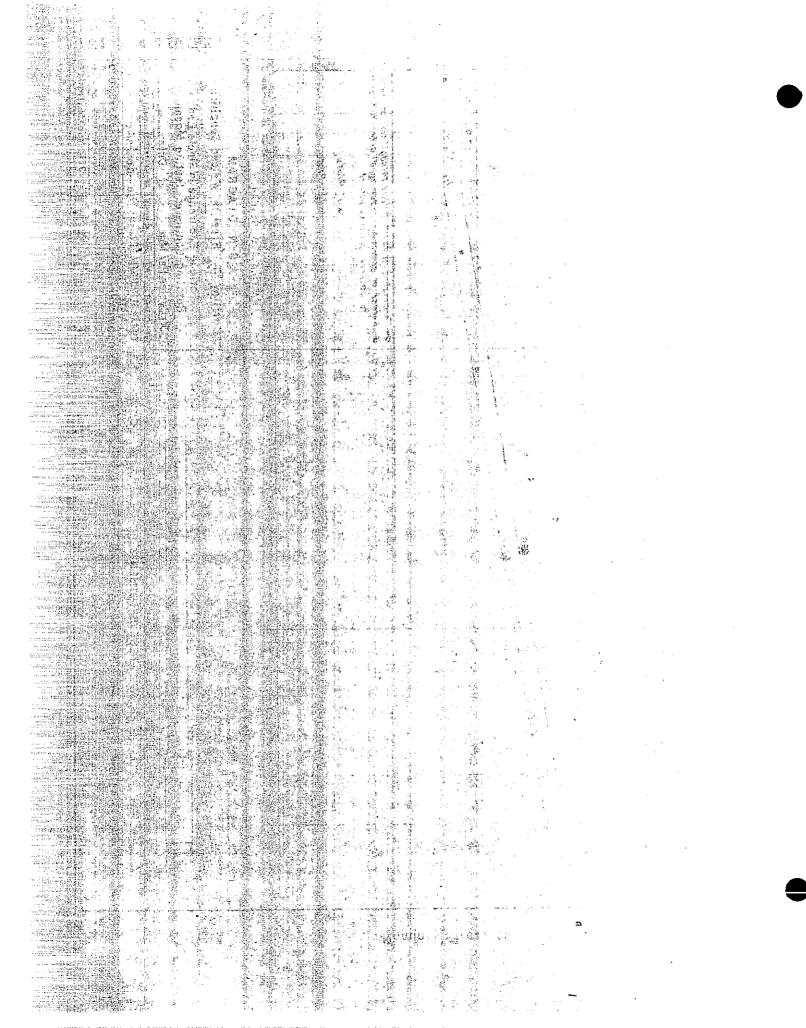
S.W. 91, LOW HYDROGEN ELECTRODES

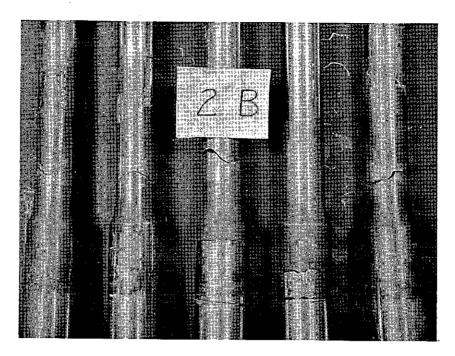
(E-11016 TENTATIVE)

and the same

937,900,051	© Terminated without failure through critical section Retest of specimen undamaged after 107 cycles to observe coaxing effect. Reference of the coaxing o	STATE OF CALIFORNIA MATERIALS 8 RESEARCH DEPARTMENT S-N DIAGRAM Carilloy "T," Steel in Welded Condition Fatigue Endurance in Single End Rotating Cantilever Testing Machine 6000 Cycles Per Min. WELD METAL-A.O.Smith, S.W. 91 VIELD STRENGTH ULTIMATE STRENGTH-112,500 ELONGATION IN 2"- 18% REDUCTION OF AREA - 31% REDUCTION OF AREA - 31% Equations based on Origin at S-0.01 Mo-0.55 TI-(0.01) 104,1 "Increment, 8" x19" Cycle S - 0.01 Mo-0.55 TI-(0.01)
©		T SPECIMEN 105 2 1
Least square Probable Errar		075" Drill 8 Tap \$ N.C. Thd 1" Deep

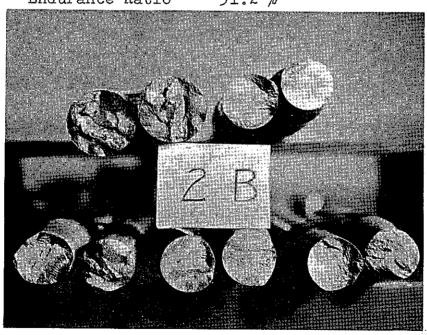
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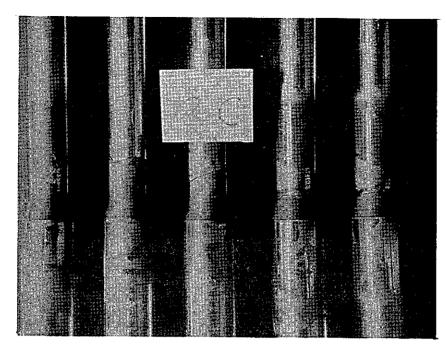


Side and end views of fatigue specimens prepared from a l inch butt joint manually welded using A.O.Smith SW91 low hydrogen electrodes. Failures started in the weld metal and the parent metal and propagated through the weld metal, heat affected zone, and the parent metal.

Endurance Limit 37,900 psi Endurance Ratio 31.2 %



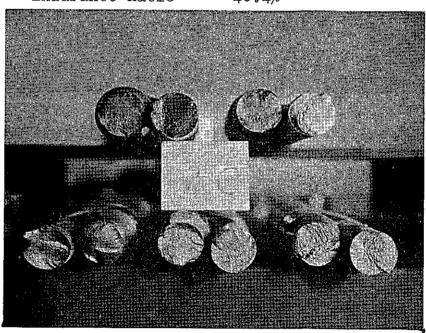
The specimen of the extreme left in both pictures contained numerous gas pockets and a separation extending over 1/4 the cross-section. Note also the break in the grip.



Side and end views of fatigue specimens prepared from a 1 1/2" butt joint manually welded using A.O.Smith SW91 low hydrogen electrodes. Failures started in the weld metal and the heat affected zone and propagated through the heat affected zone.

Endurance Limit Endurance Ratio

37,900 psi 40.4%



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MANUAL WELDING

FATIGUE FAILURE PHOTOGRAPHS

AND

SN DIAGRAMS

OF

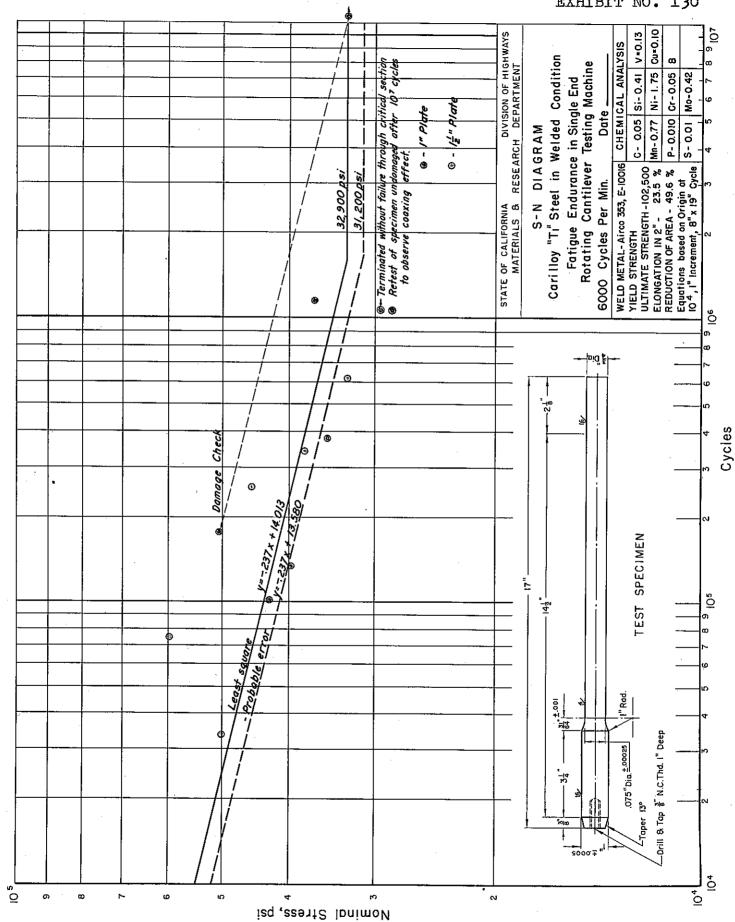
TRANSVERSE BUTT WELDS

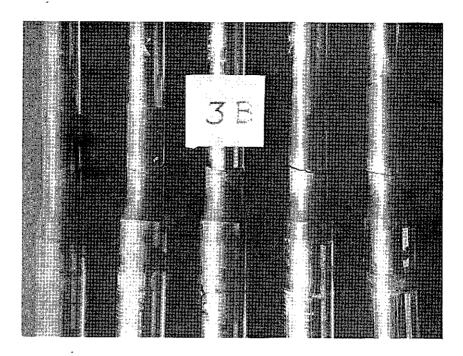
MADE WITH

AIRCO

353, LOW HYDROGEN ELECTRODES

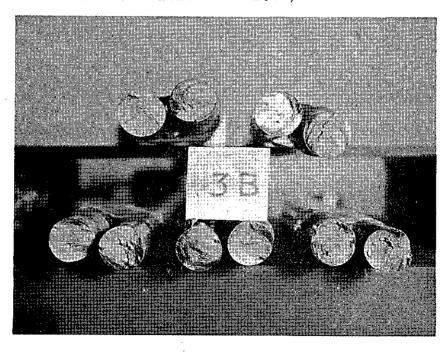
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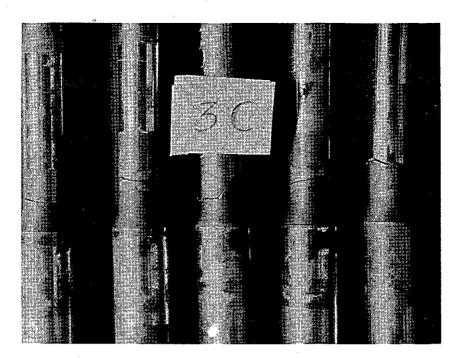




Side and end views of fatigue specimens prepared from a 1" butt joint manually welded using Airco 353 low hydrogen electrodes. Failures started in the weld metal and propagated through the heat affected zone.

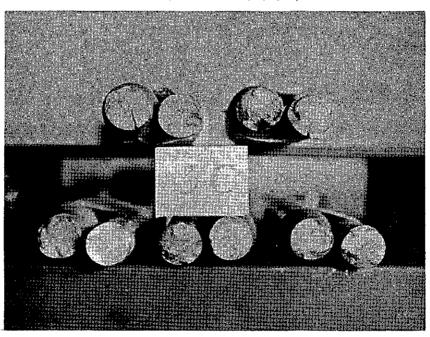
Endurance Limit 32,900 psi Endurance Ratio 21.8 %





Side and end views of fatigue specimens prepared from a 1 1/2" butt joint manually welded using Airco 353 low hydrogen electrodes. Failures started in the weld metal and propagated through the weld metal and the heat affected zone.

Endurance Limit 32,900 psi Endurance Ratio 34.3 %



AUTOMATIC WELDING

FATIGUE FAILURE PHOTOGRAPHS

AND

SN DIAGRAMS

OF

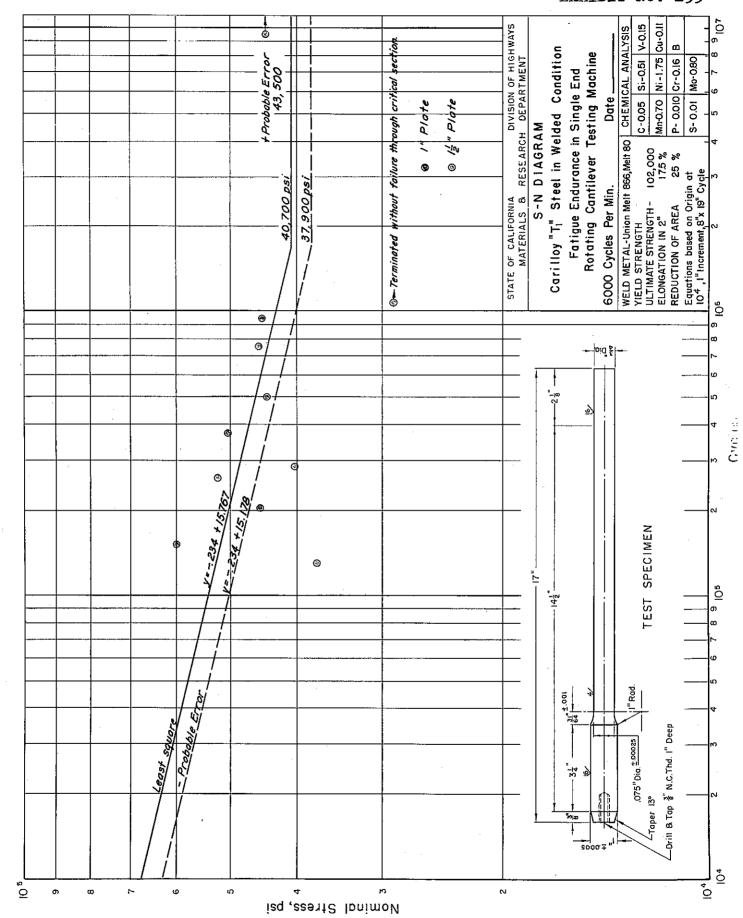
TRANSVERSE BUTT WELDS

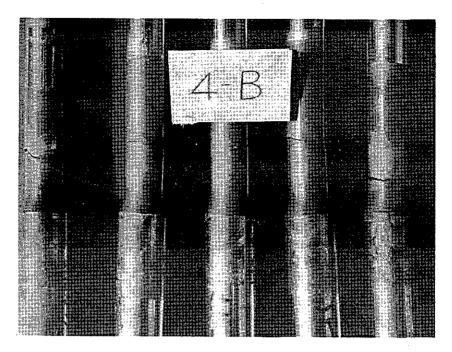
MADE WITH

UNIONMELT SUBMERGED ARC PROCESS

WITH

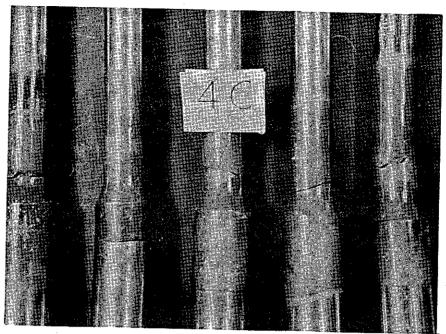
OXWELD 866 ELECTRODE WIRE AND #80 FLUX





Side and end views of fatigue specimens prepared from a l" butt joint welded with the Unionmelt submerged arc process using oxweld #866 electrode wire. Failures started in weld metal and heat affected zone and propagated through weld metal heat affected zone, and parent metal.





Side and end views of fatigue specimens prepared from a 1 1/2" butt joint welded with the Union-melt Submerged Arc process using oxweld #866 electrode wire. Failures started and propagated through weld metal, heat affected zone, and parent metal.

Endurance Limit 40,700 psi Endurance Ratio 44.9 %



Note specimen failing in grip of upper left and large slag inclusion in specimen at upper right. Bottom row specimens contained gas pockets.

SEMI-AUTOMATIC WELDING

FATIGUE FAILURE PHOTOGRAPHS

AND

SN DIAGRAMS

OF

TRANSVERSE BUTT WELDS

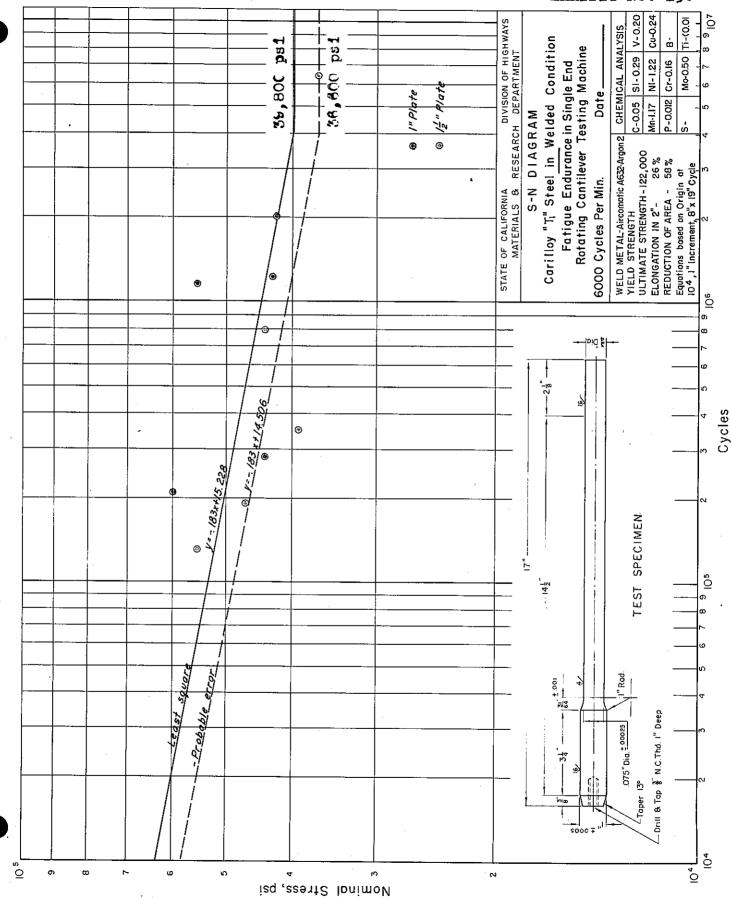
MADE WITH

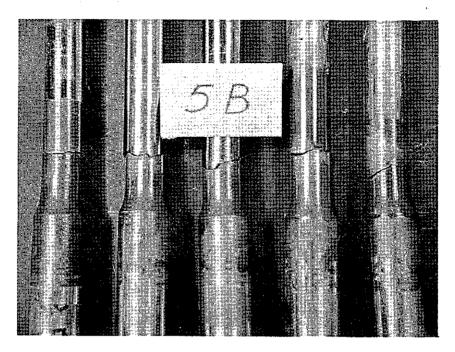
AIRCOMATIC INERT GAS SHIELDED ARC PROCESS

WITH

A632 ELECTRODE WIRE AND A 98%A-2%O2 GAS SHIELD

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Side and end views of fatigue specimens prepared from a 1" butt joint welded with the Aircomatic gas shielded are using A632 electrode wire. Failures started in the weld metal and propagated through the heat affected zone.

> Endurance Limit 39,800 psi Endurance Ratio 32.5 %

